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B R E V I O R A

Museum of Comparative Zoology

Cambridge, Mass. May 28, 1953 Number 14

RECORD OF A HERMAPHRODITIC HORSESHOE CRAB, *LIMULUS POLYPHEMUS* L.

By John P. Baptist

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A hermaphroditic horseshoe crab, *Limulus polyphemus* L., was picked up by a small scallop dredge from the channel of Plum Island Sound, Massachusetts on May 16, 1952. As far as can be determined, this is the first such *Limulus* to be recorded.

The general appearance was that of a mature male. Its width (125 mm.) was about average for males in this area. (The widths of 606 mature males measured this summer ranged from 88 mm. to 140 mm., with an average of 117 mm., while 489 mature females ranged from 130 mm. to 199 mm. in width, with an average of 155 mm.) It had mating claspers, and the anterior edge of the prosoma was curved upward in the middle, which also is a male characteristic. The left genital aperture was typically male, round and located on a definite papilla. The right genital aperture was typically female, a horizontal slit and not on a papilla (Lochhead, 1950). The genital operculum, showing both male and female genital apertures, may be seen in the upper illustration of Plate 1. On the dorsal surface of the opisthosoma near the telson were darkened areas normally present on mated females. These may be barely discernible in Plate 2. They are produced by the abrasive action of the anterior edge of the male as he clings tenaciously to the female during the mating period. Females which have mated for prolonged periods exhibit deep scars on the last pair of immobile spines, caused by the powerful claspers of the male.

Such scars were not evident on the hermaphrodite, suggesting that it had been mated as a female for a comparatively short time.

Gross dissection of the prosoma and histological sections revealed both male and female gonads. The right and anterior portions were full of eggs in various stages of development (Plate 2), comparable to to those of mature females. Histological sections of the tissue on the left side demonstrated sperm sacs full of tail-less sperm, diverticula of the hepatopancreas and connective tissue (Plate 1, lower illustration). The same structures were visible in sections of gonads from normal males. According to Benham (1885) the tails are apparently produced as the sperm approach the aperture.

The presence of both eggs and sperm confirms the external evidence that this specimen is a true hermaphrodite.

REFERENCES

Benham, W. B. S.

1885. On the testis of *Limulus*. Trans. Linn. Soc. Lond. (Zool.), (2) **2**: 363–366.

Lochhead, J. H.

1950. *Xiphosura polyphemus*. *In* Selected Invertebrate Types, edited by F. A. Brown, Jr. pp. 360–381. John Wiley & Sons, Inc., N. Y.

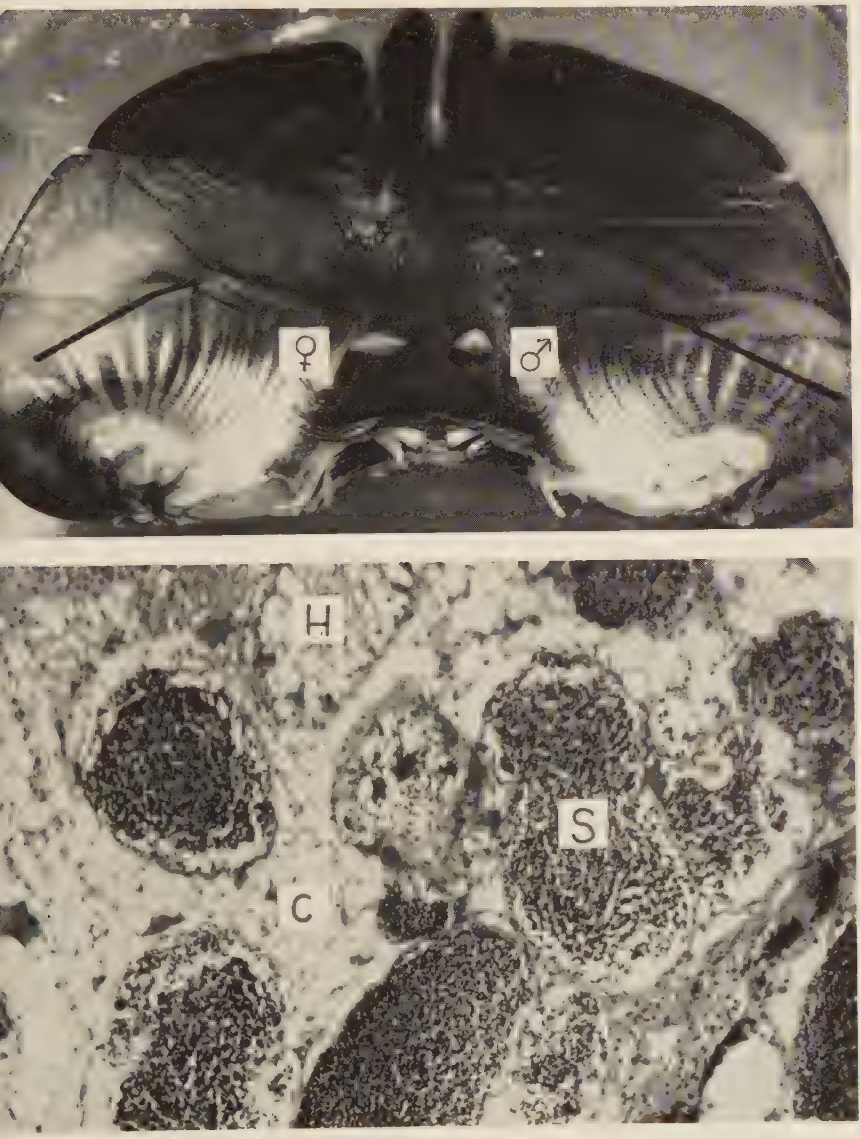

PLATE 1

Upper — Ventral view of posterior surface of genital operculum (enlarged), showing right genital aperture (♀) and left genital aperture (♂).

Lower — Photomicrograph of section through testis (X 120). *S*, sperm sacs containing tail-less sperm. *H*, hepatopancreas. *C*, connective tissue.

(Photographs by Alden P. Stickney)

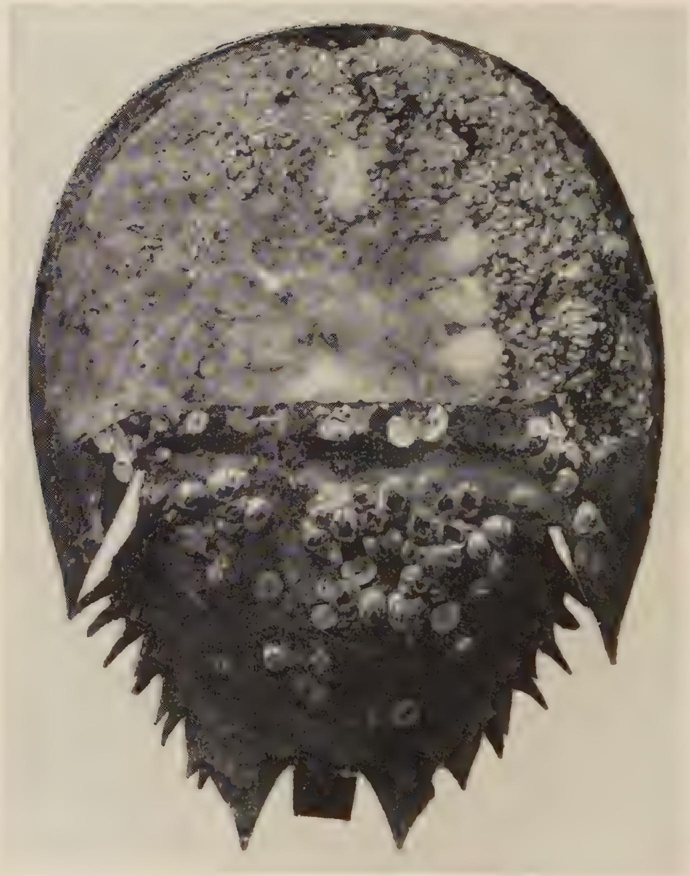

PLATE 2

Dorsal view of *Limulus polyphemus* with carapace of the prosoma removed, showing mass of eggs on the right side, but only a few scattered eggs on the left side. (Telson has been cut off). (Photograph by Alden P. Stickney.)

U.S. DEPARTMENT OF THE INTERIOR
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SALMON TAGGING BY THE 1952 JAPANESE NORTH PACIFIC FISHING EXPEDITION

By C. J. Burner*

The Japanese re-entered the salmon fisheries of the North Pacific Ocean west of longitude 175° W. during 1952[1] with a fleet of 3 motherships and 50 catcher boats. Accompanying and patrolling the fleet were three fully-equipped and heavily-staffed oceanographic-exploratory research vessels of the Japanese Fisheries Agency. These ships ranged 400 miles or more from the mothership in all directions. Their purpose was to keep the fishing fleet within the area of operations authorized by the Japanese Government and to recommend fishing areas on the basis of abundance of plankton and suitable temperatures. Thus, in 1952 the Japanese fleet fished south of the Aleutians because the sea north of the chain was considered too cold. In addition to standard oceanographic equipment, the three vessels carried nets and long lines for exploratory-fishing and salmon-tagging operations.

The tagging experiments done by the Japanese, while limited and inconclusive, clearly demonstrate that salmon can be taken in numbers and good enough condition for marking or tagging on the high seas.

Since a Bering Sea and North Pacific tagging experiment to determine the degree of mixing or demarcation of Asiatic and Alaska stocks of salmon is being considered by the U. S. Fish and Wildlife Service, the methods and results of the Japanese tagging are of considerable interest. A summary of the results of the tagging done in the North Pacific in 1952 was prepared by the Japanese Fisheries Agency and forwarded by William C. Neville, Fisheries Attache at the United States Embassy at Tokyo, Japan.

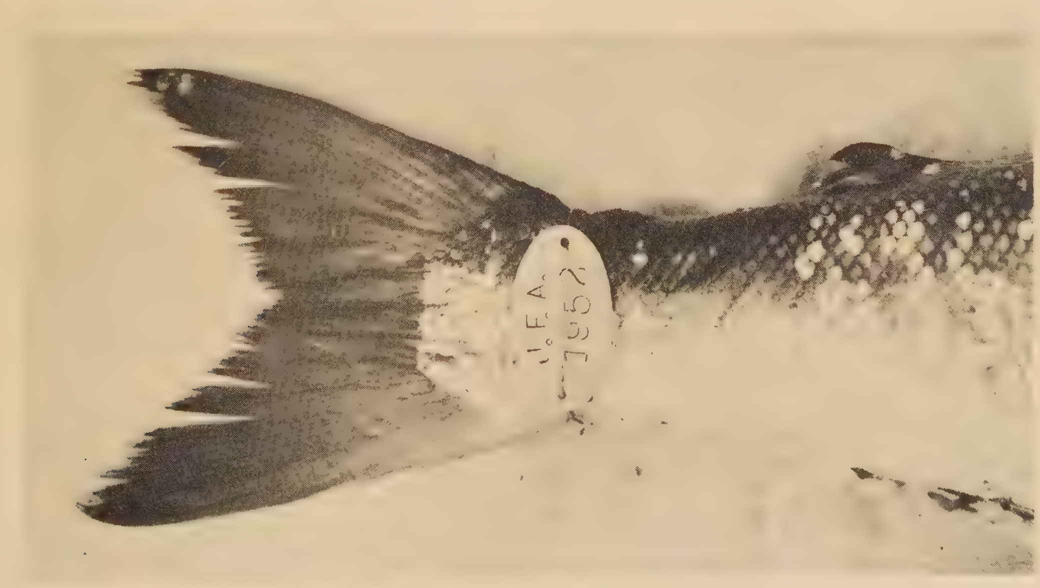

FIGURE 1 - METHOD OF ATTACHMENT OF JAPANESE CAUDAL PEDUNCLE TAG.

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[1] FOR A FULL ACCOUNT OF THIS EXPEDITION SEE FUKUHARA, F. M.: "JAPANESE 1952 NORTH PACIFIC SALMON-FISHING EXPEDITION," COMMERCIAL FISHERIES REVIEW, VOL. 15, NO. 2 (FEBRUARY 1953).

According to the report, 2,419 salmon were tagged between May 20 and June 18, 1952. Of this number 1,175 were chum salmon (Oncorhynchus keta), and 1,244 were red salmon (Oncorhynchus nerka). The tag used was a red (on red salmon) and a pink (on chum salmon) celluloid oval stamped with the letters JFA (Japanese Fisheries Agency), the year, and a serial number on the reverse side. It was attached to the fish with a 0.4 mm. silver-coated copper wire so that it encircled the caudal peduncle like a bracelet (see fig. 1). The tags are "dished" slightly to conform to the body curve of the fish.

The size of the fish tagged is given as 45 cm. to 65 cm., with a 55 cm. mean, on the basis of "forked length." This is for both species. It is possible, therefore, that all salmon tagged were mature and in the spawning year. No further data are given.

The Agency reports that gill nets were used to capture the fish prior to tagging. However, in conversations aboard the Tenyo Maru, the United States biologist F. M. Fukuhara obtained the distinct impression that long lines were also used, and that salmon thus caught were in much better condition for tagging. The Agency reports that long lines were fished, found unsuccessful, and not used for actual tagging. Dates and locations of tagging are given in the table.

Of the 2,419 salmon tagged, three fish were actually recovered in the Japanese nets, but one of them escaped. The two recaptures were chum salmon tagged on June 2 and retaken on June 5 at the following locations: Tag No. 3 (pink color) at 50°29' N. latitude, 177°45' W. longitude; and Tag No. 1206 (pink color) at 50°28' N. latitude, 177°45' W. longitude. Both fish swam approximately 14 miles in a northwesterly direction toward Kiska Island before recapture, assuming straight-line movement.

Time and Place of Salmon Tagging by the Japanese Fisheries Agency in the North Pacific in 1952

Date	Place		Date	Place	
	Latitude	Longitude		Latitude	Longitude
May 20	51°54' N.	179°56' W.	June 4	50°47' N.	179°05' W.
22	50°08' N.	177°55' W.	5	50°50' N.	179°31' W.
23	49°46' N.	179°00' W.	9	51°07' N.	178°15' W.
25	50°37' N.	179°41' W.	12	51°26' N.	179°32' W.
30	51°43' N.	177°47' W.	13	51°05' N.	179°13' W.
June 1	51°26' N.	177°52' W.	14	51°10' N.	178°19' W.
2	50°20' N.	178°00' W.	15	51°17' N.	176°09' W.
3	50°31' N.	178°23' W.	18	52°21' N.	172°49' W.

NOTE: DATA ON THE NUMBER OF FISH TAGGED AT EACH LOCATION NOT YET AVAILABLE.

Two tags (numbers unknown) were reported on red salmon passing through the weir at Egegik River, Bristol Bay, on July 1 and July 7, respectively. These tags were not recovered, but the detailed description given by the weir watchman gives some indication that the tags were placed on the fish by the Japanese Fisheries Agency a month or so earlier and about 1,000 miles away.

No conclusions are drawn by the Agency or by the Service. The few returns and the short distance traveled by chum salmon preclude any attempt to define the migratory behavior, or to distinguish the stocks of salmon in the North Pacific Ocean.

CORRECTIONS

The following errors occurred in the article "Japanese 1952 North Pacific Salmon-Fishing Expedition" by Francis M. Fukuhara, Commercial Fisheries Review, vol. 15, no. 2 (February 1953):

Page 1, paragraph 1, line 5 - "north of Atka Island" should read "west of Atka Island"

Page 4, last paragraph, line 3 - "400 miles south of Kiska" should read "90 miles south of Kiska."

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Importance of Local Environment in Oyster Growth

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Cultivation of the oyster, *Crassostrea virginica*, Gmelin, has always been dependent to some degree on the transplanting of young oysters from so-called seed areas to growing grounds. In recent decades, however, the planter has had to go progressively farther afield for his source of seed and the scarcity of seed oysters in many producing areas is a problem of increasing concern. The transportation costs involved in these operations make it imperative that the imported stock survive and grow at better than average rates. Oysters are readily transplanted many thousands of miles from the area in which they set, but stocks from some areas have been found to grow better than others. It has been shown too, as in the case of the eastern oyster transplanted to the Pacific coast, that oysters, while growing well in a new environment may fail to reproduce normally. For these and other reasons, it has become desirable, if not imperative, that the biologist study growth and mortality rates in as many different imported stocks as possible so that the best of these may be recommended to the commercial planter.

Stocks of oysters from the Pensacola area, where there is an abundant set, have been sent to several different geographical regions to develop information on this problem. In cooperation with Mr. Francis Beaven of the Chesapeake Biological Laboratory at Solomons Island, Maryland, reciprocal plantings of native oysters have been made. This paper summarizes observations on Chesapeake Bay oysters in Florida and compares their growth with that of Florida native stock.*

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* I am indebted to John R. Wiggins and John S. MacGregor, former Fishery Aids at this laboratory, for some of the measurements reported here.

The Pensacola laboratory received a supply of Chesapeake oysters in December, 1950, when they were about six months old. The edges of the oysters were broken smooth in shipment, and there was an initial mortality of 10 per cent. The oysters were separated from the natural cultch, cleaned and placed in wire trays having fifty individual compartments. Identical trays containing Pensacola spat of the same approximate age were prepared and duplicate sets of trays were placed at each of two locations, designated as East and West stations. The trays hung three feet below mean low water and were about four feet above a barren sand bottom. Length, dorso-ventral width and the weight of each oyster were recorded at regular intervals for the next 18 months, i.e., until the oysters were two years old. Water temperature and salinity levels were recorded continuously at the West station, intermittently at the East station.

During the 18 months of observation there was a total mortality in all trays of 51 per cent. The drill, *Thais*, caused 32 per cent of this mortality, the remainder (19 per cent) was due to unknown agents. This amount of mortality, 19 per cent, is expected under our experimental conditions at Pensacola, over a period of 18 months. The mortality rates in the Chesapeake group were the same as in the local oysters although more of the local oysters were lost because of drill damage in one tray which fell to the bottom. There was no consistent difference in mortality rates at the two stations or during particular seasons of the year.

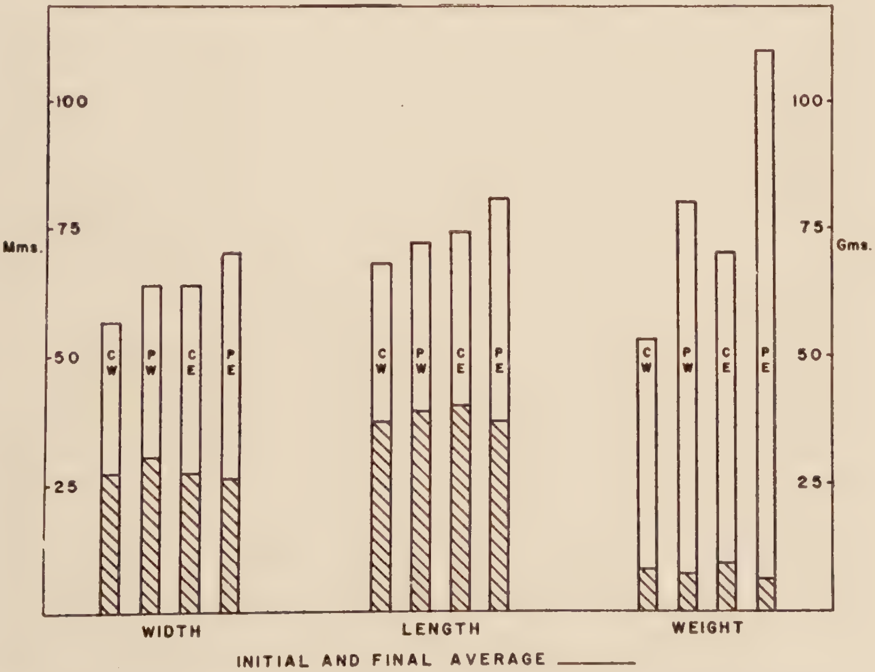

FIGURE 1. Average measurements of four groups of oysters at Pensacola, Florida in January 1951and July 1952. Chesapeake and Pensacola oysters grown at West stations are indicated by CW and PW; the same stocks grown at East station are indicated by CE and PE respectively.

During the first few months of observation the Chesapeake oysters grew especially well, and faster than the local controls. This was perhaps due to the stimulus of being moved to a new environment. This rapid growth was, of course, at a time when the oysters would have been hibernating had they remained in their original environment. At the close of the experiment, some oysters in both stocks were over three and one-half inches long but there were also many only two and one-half inches long. All oysters were well shaped, with smooth rounded shells, as a result of the routine cleanings they received. All were infested to some extent with boring sponge and it is probable that some contained the boring clam, *Martesia*. At least 15 per cent of the Chesapeake oysters were sponge infested on arrival and presumably this condition had no material effect on the final results.

TABLE 1

CHESAPEAKE AND PENSACOLA OYSTERS AT PENSACOLA, FLORIDA, 1951-1952

	Jan.	Mar.	May	July	Sept.	Nov.	Jan.	Mar.	May	July
Chesapeake-East										
Length, mms.	40	46	52	55	58	60	66	72	74	74
Width, mms.	27	35	42	43	43	45	52	61	65	64
Weight, gms.	9	12	19	28	33	40	48	58	66	70
'G'	10	19	42	66	82	108	165	255	318	332
Mortality				4	2		4			6
Chesapeake-West										
Length, mms.	37	42	47	49	52	54	59	65	67	68
Width, mms.	27	34	38	38	39	40	47	54	58	57
Weight, gms.	8	10	16	22	26	31	37	45	51	53
'G'	8	14	29	41	53	67	103	158	198	205
Mortality			2	2			10	4		2
Pensacola-East										
Length, mms.	37	43	49	55	62	66	71	78	81	81
Width, mms.	26	32	40	43	46	48	56	67	71	70
Weight, gms.	6	8	15	28	43	55	69	86	99	110
'G'	6	11	29	66	123	174	274	449	569	624
Mortality		2		4	6		6		8	4
Pensacola-West										
Length, mms.	39	44	48	51	53	56	62	67	71	72
Width, mms.	30	36	39	41	42	43	51	60	65	64
Weight, gms.	7	10	20	27	33	39	50	62	70	80
'G'	8	16	37	57	74	94	158	249	323	369
Mortality		2	2							2

Average data recorded on first day of month for four groups of oysters at two stations.

The oysters showed great individual variability in the amount and timing of growth increases, as is to be expected, but the distribution of size frequencies was normal both initially and at the close of the experiment. On a commercial basis, the performance of the entire population is of more interest than that of the extreme individual. For this reason the data are presented as that of group averages and all measurements are rounded to the nearest whole number. Data are based only on oysters surviving beyond the end of the experimental period. Of the 400 original oysters, 16 were damaged or lost, 112 killed by drills, 86 died and 188 survived. Table 1 is a summary of the pertinent data.

Figure 1 illustrates the average size of the four groups of oysters at the start and close of the experimental period. Pensacola oysters at the east and west stations are designated PE and PW, Chesapeake oysters as CE and CW respectively. Initial differences in the average measurements of the four groups were quite small and are without significance. After 18 months the four groups were clearly differentiated in size and especially in regard to weight. PE oysters were consistently the longest, widest and heaviest. The CW group was the smallest in these respects, while CE and PW occupied intermediate positions.

These data on length, width and weight may be combined arbitrarily into a single factor representing growth in the several dimensions simultaneously.

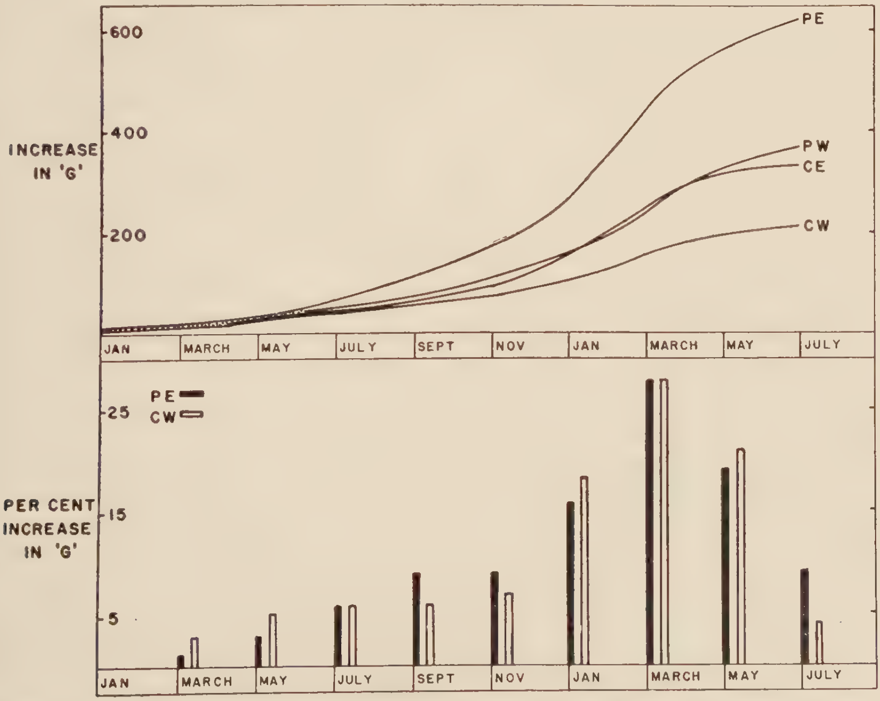

FIGURE 2. Bimonthly increases in calculated 'G' factor in four groups of oysters, where 'G' is product of length, width and weight divided by 1000. Percentage increase in 'G' when total 'G' for 18 months is considered to be 100. Pensacola East oysters, PE, attained largest average size; Chesapeake West oysters, CW, attained smallest average size.

This factor, which is termed 'G', is the product of length, width and weight, divided, for convenience, by 1000. In this study, the 'G' factor ranged from six in the young oysters to over 600 in the PE group, at 18 months. In Figure 2, the upper graph shows increases at bi-monthly intervals of the calculated

'G' factor for the four groups of oysters. These curves indicate clearly the distinctive nature of the growth increases in the different trays of oysters. During the first six months there were no sharp differences in average data, although the pattern of growth was clearly established. From this time until the end of the following year differences between the groups became accentuated. The uniformity of the several growth patterns was such that monthly gains in any three groups could have been predicted by the performance of the fourth group. This uniformity indicates that the factors controlling growth in the different groups were permanent features of the internal or external environment and not seasonal in nature.

These data may be presented in another way, to consider the total 'G' for the 18 months to be 100 and then indicate the per cent increases in 'G' at regular intervals. Such data are shown in the lower graph of Figure 2 for the fastest and slowest growing groups, PE and CW. It is important to note here that percentage increases in these groups are very similar, sometimes identical, at each time interval throughout the experimental period. Data for groups PW and CE, although not shown, possess the same pattern. Up until the last observation, increases in any one period for all four groups of oysters do not vary by more than four per cent of the total. It is justified to conclude then, without regard to actual growth in grams and millimeters, that all four groups grew at nearly identical rates in terms of their capacity to grow. This implies, further, that the rate of metabolic activity in each group was influenced to a similar degree by the environment. This is an expected conclusion, considering that temperature levels paralleled each other at the two stations. It is believed that this means that temperature, and probably salinity also, can be eliminated as decisive factors in producing the different growth patterns.

Despite similarities in rates of growth, the four groups of oysters attained quite different final sizes. This may be shown most clearly by tabulating the final 'G' factor for each group:

PE — 624
PW — 369
CE — 332
CW — 205

If the group with the lowest rating is reduced to unity, relative growth may be represented approximately as follows:

PE — 3X
PW — 1.5X
CE — 1.5X
CW — X

The data on any one of the measurements, such as length, width or weight could be treated in the same manner, but when this is done the distinctions between the four groups become less obvious.

This tabulation makes certain relationships apparent. Oysters at the East station did at least half as well again as the same stocks at the West station; the Pensacola oysters at each station grew at least half again as well as the Chesapeake oysters. The PW and CE oysters grew approximately as well as each other; the PE oysters grew three times as well as the CW group. It must be concluded from these facts that not only is the environment at the two stations fundamentally different, but also, that local oysters grow far better than Chesapeake oysters in this area.

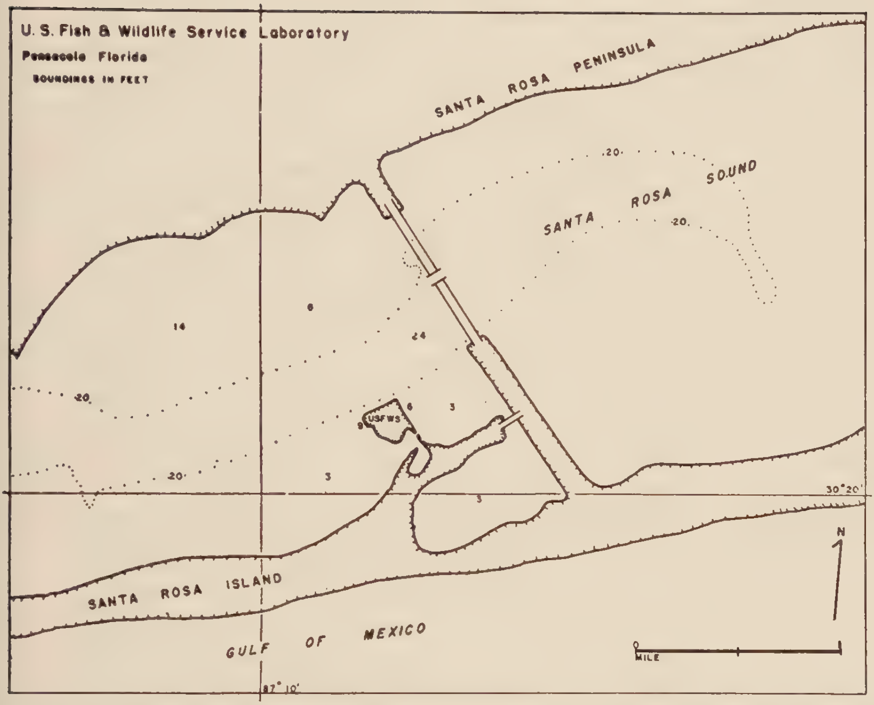
U. S. Fish & Wildlife Service Laboratory
Pensacola Florida
SOUNDINGS IN FEET
SANTA ROSA PENINSULA
SANTA ROSA SOUND
20
20
14
6
24
20
USFWS
9
6
3
20
3
3
30°20'
N
SANTA ROSA ISLAND
GULF OF MEXICO
MILE
87°10'

FIGURE 3. Location of laboratory island, USFWS, near Pensacola Florida. East and West stations are located at 6 and 9 foot soundings shown on either side of laboratory island and are 1000 feet apart.

The location of the two stations should assist us in interpreting these results but instead presents an additional problem. The diagram in Figure 3 shows the locations of the stations at the 6 and 9 foot sounding on either side of the laboratory island. The stations are not more than 1000 feet apart; they are exposed apparently to the same water currents; temperature and salinity levels parrallel each other. So far as can be determined without extensive chemical analyses, the two stations are similar, except that at one the morning sun is dominant and at the other the afternoon sun. Nevertheless, differences between samples of the same stock of local oysters placed at the two stations were greater in some instances than the differences between local oysters and oysters transplanted here from Chesapeake Bay, over 700 miles away.

It is fortunate that these plantings were made reciprocally at the two stations. Suppose that an investigator had made test plantings of a similar nature, but not using as many samples. Since a thousand feet between plantings is not ordinarily considered of importance, any one of the following combinations of plantings might have been made:

a. PE and CW
b. PE and CE
c. PW and CE

In these three selected combinations, the following conclusions would have been inevitable:

a. Pensacola oysters grow three times as well as Chesapeake oysters,
b. Pensacola oysters grow twice as well as Chesapeake oysters, or
c. Pensacola oysters and Chesapeake oysters grow equally well.

Unfortunately, such anomalous conclusions are much more than a theoretical possibility in an incompletely controlled test planting.

It would be desirable to go on from this point and describe the environmental factors which differentiate the east and west stations, but the data necessary to interpret this situation are not available. Of greater importance is the fact that it is not certain what data are necessary to interpret this situation. Until the superiority of one location a thousand feet from another can be accounted for it is not possible to interpret or predict the results of moving oysters up and down the coast—except on a trial and error basis.

From the little data available, there appears to be no logical explanation for the different results obtained at these two stations. The apparent continuity of water currents between the two areas would seem to preclude the existence of local concentrations of some water-borne factor. The absence of natural populations of oysters, or concentrations of other sedentary organisms, eliminates from consideration the possible effects of population densities. These conditions, combined with the similarity in the physical arrangement of the test oysters at the two stations, leaves little basis for profitable speculation on what factors are involved.

When the reasons for the poor growth of the Chesapeake oysters as compared to the local stock at the same station are examined it is equally difficult to arrive at any satisfactory conclusions. Mr. Beaven states that Pensacola oysters transplanted to Chesapeake Bay grow at slower rates than the native oysters. Thus it appears that each of these stocks of oysters does best in its own environment. This is certainly not due to an inherent adaptation to a warmer or colder climate. The slow growth pattern of the Chesapeake oysters was well established here before the water became any warmer than it is customarily in Chesapeake Bay. Nor can it be assumed that these oysters in the six months prior to transplanting became so accustomed to the local food supply that they were unable to adjust completely to the food in the new environment. The seasonal variation in the variety of plankters at either one location is probably as great as the differences in the plankton between Chesapeake Bay and Pensacola. There are numerous instances of transplants growing much better when their environment had been changed radically. No explanation is offered at this time for the observed differences in these groups of oysters.

It seems desirable that biologists make special efforts to examine in all possible detail the factors which interact to make a particular environment more or less suitable for oysters. A concerted attack on this problem may be far more productive than the wide-ranging surveys of oyster producing areas which have occupied so much of the investigators' time in the past. It is hoped that considerable effort can be devoted to a comprehensive study of the situation described here. The stations are convenient to the laboratory, and the fact that the essential differences must not be seasonal or sporadic, but exist throughout the year, makes this situation especially promising for an intensive investigation.

U.S. DEPARTMENT OF THE INTERIOR
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SEP. NO. 352

OYSTER GROWTH AS AFFECTED BY LATITUDINAL TEMPERATURE GRADIENTS[1]

By Philip A. Butler*

INTRODUCTION

The complexity of growth processes in animals makes necessary the use of many different yardsticks for a critical evaluation. The word growth itself is difficult to define but is interpreted, usually, as meaning permanent changes in length or volume. In oysters, growth is especially difficult to study since the body is hidden between the valves. Body size fluctuates seasonally; even the shell may decrease in length under special environmental conditions. Specimens taken from upper Chesapeake Bay after a prolonged period of low salinity showed that the occupied portion of the valves had decreased by an inch. Under such adverse conditions there is considerable body shrinkage and the oyster forms new valve margins within the old shell thus decreasing its total length by as much as one-third. This negative, or reductional, growth is common to many animals and frequently occurs in oysters. Most often the valves do not reflect these transitory body changes and body size cannot be determined without opening the shell. Measurement of growth in oysters is further complicated by the absence of a definitive size and by the fact that sexual maturity may be attained at shell sizes varying from ½ to 2 inches.

For these and other reasons biologists and fishermen are prone to accept shell length as a valid criterion for oyster growth, and certainly it is the easiest measurement to use. State laws regulating oyster harvesting follow suit and the 2½ or 3-inch "market" oyster is a legal standard in most areas where oysters are harvested commercially. However, since the amount of meat in an oyster rather than the size of the shell determines the profit, we find that private oyster growers do not necessarily use the 3-inch standard to determine the harvesting time for their crop. Under most conditions, the private planter determines the harvesting period by the number of pints of meat produced from a bushel of oysters rather than on whether or not the oysters will pass the minimum legal standard. In some areas too, the commercial canner does not purchase oysters on the basis of length but rather on how many cans of meat he can process per barrel of shell stock. Shell growth is, of course, intimately associated with body growth, but the relation between these two is by no means directly proportional. Investigators have recognized these facts for a long time. But, unfortunately, there are occasional reports of rapid increases in shell length which, with or without the writer's intention, are interpreted as meaning rapid meat production. The reading public has been educated to consider shell growth as synonymous with meat growth.

LENGTH VERSUS WEIGHT-VOLUME FOR DETERMINING GROWTH

The difficulty in determining oyster growth from length measurements becomes apparent on examining the results of some of the many experiments we have conducted during the past four years. For example, observations on growth under average conditions show that during the summer months of their first year oysters grow up to 60 mms. in length; during their second summer they may increase from 1 to 10 percent. During the summer months of their third year there is virtually no increase in shell length, although weight and volume may increase from 10 to 20 percent. Obviously, during this third summer the oysters are growing despite the lack of increase in length. Length increases do take place in the third year of course, but during the colder months. In contrast, oysters in the colder waters of New England add 70 percent of their annual length increment during the four summer months when mature Gulf oysters are not growing appreciably.

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[1] BASED ON A PAPER PRESENTED AT THE NATIONAL SHELLFISHERIES ASSOCIATION CONVENTION IN ATLANTIC CITY, N. J., AUGUST 14, 1952.

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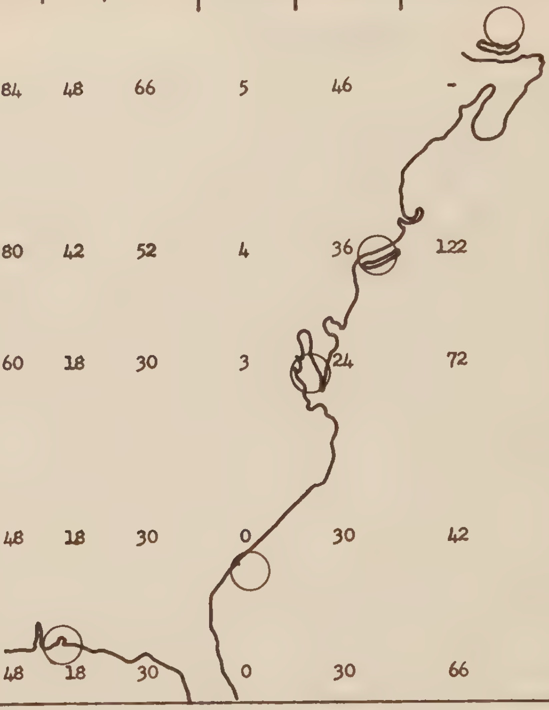

Location	Mean annual temp. 0° C.	Calendar months to grow select oyster			Months in hibernation	Average no. of growing months	Oz.-yield per bushel (USFWS statistics)	Oz.-yield per bushel (biologists' estimate)	Oz.-yield per calendar month	Oz.-yield per growing month
		Poor area	Best area	Average area						
CANADA	6	84	48	66	5	46	-	120	1.8	2.6
LONG ISLAND SOUND	10	80	42	52	4	36	122	120	2.3	3.4
CHESAPEAKE BAY	15	60	18	30	3	24	72	96	3.2	4.0
SOUTH CAROLINA	20	48	18	30	0	30	42	76	2.5	2.5
GULF OF MEXICO	22	48	18	30	0	30	66	72	2.4	2.4

FIGURE 1 - ESTIMATED AVERAGE GROWING TIME AND MEAT YIELD FOR SELECT 3-INCH OYSTERS AT DIFFERENT LATITUDES. YIELD PER MONTH IS DERIVED FROM BIOLOGISTS' ESTIMATE OF YIELD PER BUSHEL.

Interesting changes in growth rates may be obtained experimentally by simulating the tidal conditions to which many oysters are normally exposed. At Pensacola we compared oysters growing under these conditions with control oysters held continuously below the water surface. In the first six months of observations, control oysters gained 35 percent in length and width while experimental oysters showed no gain; control oysters increased 160 percent in weight and experimental oysters 100 percent in weight. In another series of observations we separated oysters growing under very crowded conditions and placed them in individual trays. In the following six months these oysters increased in length only 1 percent, showed no change in width, but increased 40 percent in volume.

It is apparent that under a variety of environmental conditions essentially no changes in length and width may occur while substantial gains are being made in weight and volume, in other words, when the oyster is growing. Our observations in Florida show that significant increases in weight and volume occur each month throughout the year, whereas increases in length and width follow a well-defined seasonal pattern after the first year and occur primarily in the winter months. The regularity of volume increases during all of the growing months as compared to periodic length and width increases has been reported also for New England oysters (Loosanoff 1949). I suspect it is a characteristic of this oyster wherever it grows. For these reasons, the measurement of volume is a far more critical yardstick in the measurement of growth than is the measurement of length. There are certain disadvantages in the use of volume measurements as criteria for oyster growth. It is more time consuming and requires more equipment, but the data obtained are of much greater value for interpreting growth changes under both experimental and natural conditions.

RELATIVE VALUE OF GROWING AREAS

The oyster biologist is interested not only in growth rates in a given environment, but also is frequently concerned with the relative value of two or more growing areas. It may be possible to examine such areas only briefly. In these circumstances, the use of the total volume measurement by itself is of little value in assaying the growth potential of the oyster population. The reasons for this are obvious considering the striking differences found in the character of the shell. In areas infested with boring sponge and clams, the valves may be massive and yet enclose relatively little meat. Conversely, in areas of rapid growth, with the production of thin shells and relative thin oysters, the meat yield may be quite high. Even in circumscribed areas, variations in population density and types of cultch radically influence shell thickness and thus affect the relationship of total oyster volume to meat yield. We have several series of data illustrating these differences and our results parallel those obtained by H. F. Moore in his experimental plantings in Louisiana at the turn of the century (Moore 1910). Moore found in seed plantings of similar age that crowded oysters averaged greater length but only half the meat production of uncrowded oysters; that oysters growing on clam shell cultch produced the same amount of meat per bushel as larger and longer oysters growing on oyster shell cultch in the same area. Thus, in comparing oyster samples even from adjacent reefs, neither greater length nor greater volume is necessarily an index of greater meat yield.

TOTAL OYSTER VOLUME TO SHELL VOLUME INDICATES POTENTIAL YIELD

It is a simple operation to shuck measured samples of oysters from one or several locations and determine the relative yield at harvest time. However, for the biologist who may wish to determine the potential yield of a particular area or type of culture technique, it is much more difficult. He must sample oysters both in and out of season, when they are spawning and when they are hibernating. Under varied seasonal conditions, the yield from a sample may have little bearing on what those same oysters would produce under the optimum conditions found at harvest time. For example, we determined the yield of similar-aged oysters growing as "singles" and another group growing under crowded conditions. In May, the single oysters produced 30 percent more meat than did the crowded oysters. Two months later the yield ratio had reversed and the crowded oysters produced nearly 25 percent more than the singles. This change in meat production was not due to any sudden improvement in the crowded oysters but simply to the fact that they were heavy with spawn while the single oysters had all completed the spawning process. There are still other local conditions which may contribute to such misleading results, and it is essential for the biologist to have some yardstick usable at any time to evaluate the potential yield from an oyster population at its peak of condition.

We have found in our work that the ratio of total oyster volume to shell volume provides such a yardstick. Under poor growing conditions, where meat yield is low, this ratio approaches but, of course, never reaches 1.0. As oysters improve in meat-yielding capacity, this ratio approaches and may surpass 2.0. In other words, the larger the body space in proportion to shell, the higher the ratio. In the Pensacola area, the best oysters have a total volume:shell volume ratio of about 1.8 and the poorest oysters have a ratio of about 1.2.

This ratio has many convenient uses, some of which I shall indicate briefly: since it is based on the total internal capacity which the oyster has at some time created for its body, this ratio reflects the volume of oyster meat when the animal is, or was, at peak size; this ratio is independent of meat volume at the time of examination and hence is not affected by seasonal fluctuations in meat quality, or by variations due to spawning, etc.--it can even be used on the intact shells of oysters long dead; it eliminates the subjective impressions gained from rapid shell growth and over-all large-appearing oysters; when used in conjunction with meat volume, the ratio helps to evaluate the effects on body size of disease, pollution, and semi-permanent environmental changes.

We have found this ratio useful in comparing oysters grown under different experimental conditions in adjacent environments, and it should be equally useful in comparing oysters which have grown in environments widely separated geographically.

Since distinctive differences in the meat yield per bushel exist in the commercial production of oysters at different geographical locations, it is of interest to learn whether these differences have a biological foundation based on the oysters' ability to grow or whether they are artificial differences based on harvesting techniques.

The U. S. Fish and Wildlife Service in compiling production figures for the several oyster-growing areas makes use of certain factors for converting bushels of oysters harvested to pounds of meats produced (Anderson and Peterson 1952). These conversion factors vary from over 7 pounds per bushel in New England to less than 3 in South Carolina. These figures indicate to some extent the quality of the oysters, but they reflect primarily the harvesting methods used in the different states. In order to estimate the meat-yielding capacity of oysters from different geographical areas, it is necessary to determine the meat yield and age of a standard-size oyster. I have selected for this purpose the 3-inch "market" oyster, taking into consideration the number of calendar months necessary to produce such an oyster and in how many of these months the oyster actually grows. (Many biologists have contributed helpful information for my use in compiling these data, and I wish to express here my appreciation for their assistance.[2] I wish to emphasize, too, that any faults in the interpretation of this material are entirely my own.)

DIFFERENTIAL OYSTER GROWTH AT DIFFERENT LATITUDES

Although some of the data are quite meager, I believe that a clear-cut differential in oyster growth does exist at different latitudes. The Chesapeake oyster produces the greatest volume of meats in unit time on the basis of both calendar months and growing months. If we consider rate of growth from the biological point of view, rather than the commercial, and eliminate the hibernation months, oysters in the warmest areas produce the least amount of meats in unit time, and the other regions considered are intermediate.

The relatively poor growth of the southern oyster suggests that the Gulf of Mexico is on the periphery of the geographical distribution for this species, Crassostrea virginica. It suggests too, that parts of the Gulf may be classified as a distinctly marginal environment. Although there is clear evidence for the existence of enormous populations here in the recent past, we have no knowledge of the annual recruitment in these populations. It may well be that in the presence of static population levels overfishing by man has been the decisive factor in causing the rapid decline of the species in such areas as the Texas coast. This hypothesis may explain man's failure to restore barren areas by small-scale plantings. It is reasonable to assume that in marginal areas and in the presence of many enemies the oyster can perpetuate itself only when the adult population is very large. Admittedly, there are other areas in this latitude which provide an excellent environment for oyster populations. This situation merely emphasizes the fact that the suitability of an environment is dependent on the interaction of many ecological factors. Any single factor, such as the temperature gradient, is rarely a limiting factor in the survival of the species, although it may have far-reaching effects on the quality of the individuals making up the population.

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[2] R. R. LOGIE, FISHERIES RESEARCH BOARD OF CANADA; G. F. BEAVEN, DEPARTMENT OF RESEARCH AND EDUCATION, MARYLAND; J. G. GLANCY, BLUE POINTS COMPANY, NEW YORK; J. B. ENGLE, U. S. FISH AND WILDLIFE SERVICE, MARYLAND; G. R. LUNZ, BEARS BLUFF LABORATORY, SOUTH CAROLINA.

These conclusions are not contradicted by reports of rapid shell growth in southern oysters (Ingle 1950). Although 3- to 4-inch oysters are frequently grown in the Gulf States in a year's time and 6-inch oysters in 30 months are not rare, oysters occasionally attain a length of 3 inches in 6 months in the Chesapeake Bay and 6-inch specimens have been reported that were only 17 months old (Beaven 1952). Because of the hibernation period at this latitude, these 6-inch specimens represent approximately 15 months of growing time. Surprise has been expressed in the literature (Gunter 1951) that Gulf oysters may increase as much as 0.3 mms. per day in shell length, but this may be compared with the 6-inch Chesapeake Bay oysters which must have grown at similar or faster rates. All of these examples describe a few unusual oysters or oysters growing under exceptional circumstance, and hence do not present a true picture of average growth rates. Moreover, oyster-shell length is of only relative importance in determining meat yield. In South Carolina, for example, clustered reef oysters with an average length of 3 inches are harvested when 2 years old and yield approximately 42 ounces of meats per standard bushel. Select single oysters growing in this area may require 3 years to attain the same length, but yield up to 120 ounces of meats per bushel.

In discussing the reasons for the apparently greater meat yield of oysters grown in colder waters, we need not consider the obvious differences resulting from the harvesting of cultivated oysters in the North as contrasted with the harvesting of clustered reef oysters for canning purposes in many southern areas. I should like to mention, however, that harvesting techniques may be of greater importance than the environment in determining the meat yield from oysters as well as from any other aquatic farm crop.

Oysters in northern areas are harvested primarily at or near hibernation temperatures when they have naturally accumulated the maximum amount of food reserves. In southern areas, where hibernation temperatures are the exception, the oyster does not build up large food reserves in its tissues and during the harvesting season its energy requirements are supplied by daily food consumption. As a result, the meats are smaller on the average than meats from oysters harvested in colder waters. This hypothesis is corroborated by circumstances occasionally found in the South. In some years sudden increases in water temperatures well above the level necessary for mass spawning may exist for some time before any spawning takes place in the spring (Hopkins 1935). In my opinion this is because the oysters, having little stored glycogen available, require days or even weeks to accumulate sufficient food material for the maturation of the gonads. Geographical differences in oyster-meat production have in the past been attributed to salinity differentials in the growing areas, i.e., greater production from more saline waters. However, I suggest that the effects of the temperature gradient offer a more logical explanation for these production differences.

We should recognize why oysters living in cold waters are able physiologically to store more food reserves than warm-water animals. The reasons underlying this condition justify the conclusion that northern oysters grow faster than southern oysters. Scientists have learned that the rates of many biological processes are dependent on temperature. The temperature coefficient for such biological processes, or Q_{10} as it is called, is approximately 2. This means that for each 10-degree rise in temperature within the tolerance levels of the animal, the speed of metabolic activity is approximately doubled. In the case of the oyster, we may interpret this to mean that month by month throughout the year, minimum food and oxygen requirements of the southern oyster are about twice as great as for the northern oyster. Since this greater food requirement is accompanied by a presumed decrease in food availability in the South, it appears reasonable that southern oysters have to devote much more of their energies to the problem of existing. Although water pumping and feeding rates may be similar at different temperature levels, the percentage of food consumed which can be devoted to body building, that is to growth and to storage, must be significantly greater in New England, for example, than it is in the South Atlantic and Gulf areas.

SUMMARY

1. Field and experimental observations indicate that volume rather than the customary length measurements provide a more critical evaluation of growth in the oyster.

2. The ratio of total oyster volume to shell volume provides a useful single index for estimating the meat-yielding potential of an oyster population when continuing observations are impractical.

3. Oyster growth varies geographically, responding to differences in the latitudinal temperature gradient.

4. Oysters in the latitude of Chesapeake Bay tend to grow faster and produce more meat in unit time than oysters growing north or south of this region.

LITERATURE CITED

ANDERSON, A. W. AND PETERSON, C. E.
1952. FISHERY STATISTICS OF THE UNITED STATES 1949. U. S. FISH AND WILDLIFE SERVICE STATISTICAL DIGEST NO. 25, 298 PP.

BEAVEN, G. F.
1952. PERSONAL COMMUNICATION.

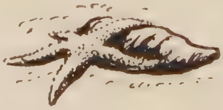
GUNTER, G.
1951. THE WEST INDIAN TREE OYSTER ON THE LOUISIANA COAST, AND NOTES ON GROWTH OF THREE GULF COAST OYSTERS, SCIENCE, VOL. 113, NO. 2940, PP. 516-17.

HOPKINS, A. E.
1935. FACTORS INFLUENCING THE SPAWNING AND SETTING OF OYSTERS IN GALVESTON BAY, TEXAS. BULL. U. S. BUR. FISH., VOL. 47, PP. 57-83.

INGLE, R. M.
1950. SUMMER GROWTH OF THE AMERICAN OYSTER IN FLORIDA WATERS. SCIENCE, VOL. 112, NO. 2912, PP. 338-9.

LOOSANOFF, V. L. AND NOMEJKO, C. A.
1949. GROWTH OF OYSTERS, O. VIRGINICA, DURING DIFFERENT MONTHS. BIOL. BULL., VOL. 97, PP. 82-94.

MOORE, H. F. AND POPE, T. E. B.
1910. OYSTER CULTURE EXPERIMENTS AND INVESTIGATIONS IN LOUISIANA. REPORT U. S. COM. FISH. 1908. BUR. OF FISH., DOC. NO. 731, 52 PP.



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THE SIGNIFICANCE OF ORGANIC COMPOUNDS IN SEA WATER

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Introduction

Since the time of Pütter (1909) much effort has been expended on the problem of the direct utilization of dissolved organic compounds by marine organisms. Most of the consideration has been on the basis of total carbon in conjunction with such criteria as over-all growth and respiratory equivalents. As recently as last year Jørgenson (1952) stated: ''It is not finally settled whether filter feeders obtain their food from the particulate fraction only, or whether they are also able to utilize the so-called dissolved organic matter in the sea.'' The use of the term ''dissolved'' is to some extent ambiguous and in the sense used here should be considered to include colloidal organic materials. Fox *et al.* (1952) and Goldberg *et al.* (1952) have developed methods for collecting these materials (not necessarily those which are dissolved in the strict sense) by a special filtration technique. They introduced the term *leptopel* to include the finely divided particulate materials and organic dispersions. Their quantitative results were given in terms of total carbon.

A somewhat different approach has been taken by Wilson (1951, 1952) who adapted a type of bio-assay to the demonstration of the biological differences between waters of different origins. Cooper (1951) conducted a brief chemical study of the areas involved and found that the water which was most favorable to the development of the invertebrate larvae used as test organisms by Wilson came from the areas showing a comparatively high rate of phosphate regeneration. It was not claimed that the phosphate was the critical factor, but simply that the phosphate regeneration indicated a level of biological activity at which growth promoting substances might have been formed.

Fox (1950) gave a general review of the metabolism of detritus as food for detritus feeders and discussed briefly the lipochromes to be found in the sediments. Kalle (1949) reported certain yellow substances which he isolated from the sea water and which fluoresce under ultraviolet light.

In 1948 my co-workers and I (Collier *et al.,* 1950) began an investigation of this problem along an entirely different line. This approach was based on the study of the existence of specific organic compounds in natural sea waters and their effects on marine organisms. We started out by testing for tyrosine-tryptophane and carbohydrates. It soon developed that there were susbtances present which influenced the rate of filtration of the oysters and which responded to the carbohydrate test used (N-ethyl-carbazol). This was encouraging, for it meant that we had found a biologically active compound (or group of compounds) to which an organism would respond quantitatively.

These findings bring into sharp focus for the marine biologist Lucas' (1949) treatment of external metabolites, or ectocrines, as he called them.

PROGRESS IN WORK ON SPECIFIC COMPOUNDS FOUND IN SEA WATER

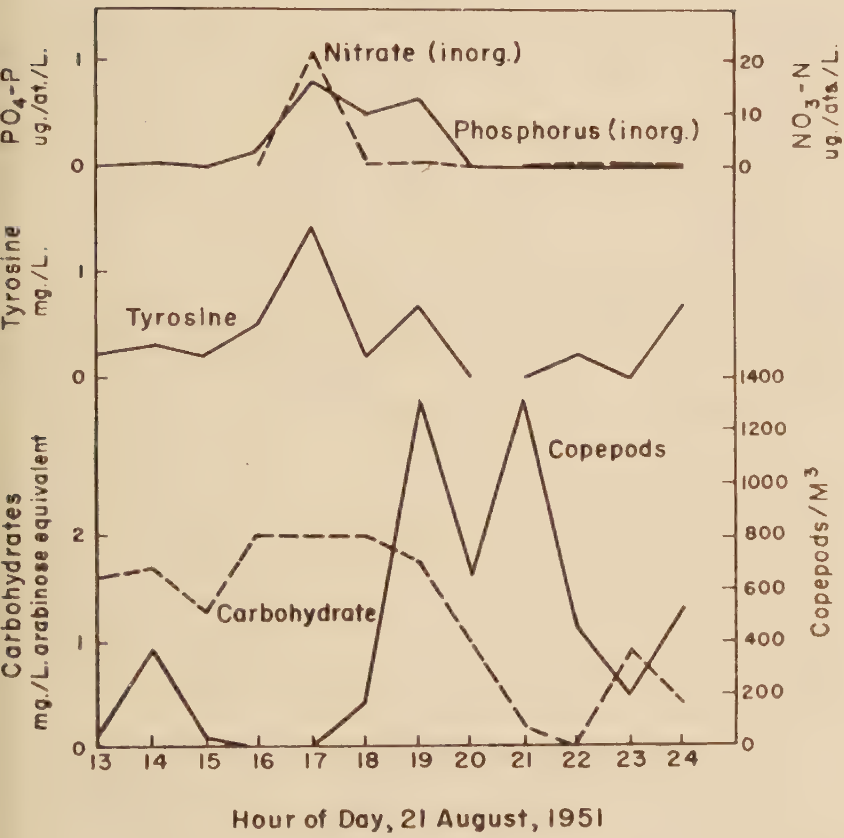
In general, we would expect all sorts of compounds to be present as degradation products of dead and dying animals and plants. Also, we would expect some quantity of excretory products, as well as diffusable metabolites which passively escape the more permeable boundaries of plant and animal masses. Some could result from extrinsic bacterial activity and many others from an intrinsic enzymatic system. The general scheme for this complex set of factors is graphically figured by Fox (*loc. cit.*).

Neritic waters can be viewed much as the mammalian physiologist would view blood: as a transport system charged with living cells and agglomerates of proteinaceous and carbohydrate complexes, as well as dissolved gases. There is good reason for the marine biologist to approach the problems from the point of view of blood chemistry. The following is a brief outline of some of the progress on specific compounds or classes of compounds being studied at the Galveston laboratory.

The N-ethyl-carbazol substances ("carbohydrates"). There are substances in sea water which respond as carbohydrates to the N-ethyl-carbazol test. These may or may not be true carbohydrates, and until we are certain of their identification the provisional term "N-ethyl-carbazol substances" has been adopted. Accordingly, the values given as "carbohydrates" are always in terms of arabinose equivalents because we use arabinose standards for reference. We have isolated and concentrated two substances which respond to the test and our chemists are now at work on the identification of these compounds.

We make routine determinations of these substances on all of our oceanographic stations. They are not homogeneously distributed at all, and we feel that they are associated with phytoplankton production. The reasons for this are: (1) in the early work (Collier *et al.*, in press) we found that in five-gallon bottles the production of the substances was associated with light as well as with aeration; (2) there was a clear diurnal variation of concentration in the natural waters, with

Figure 1

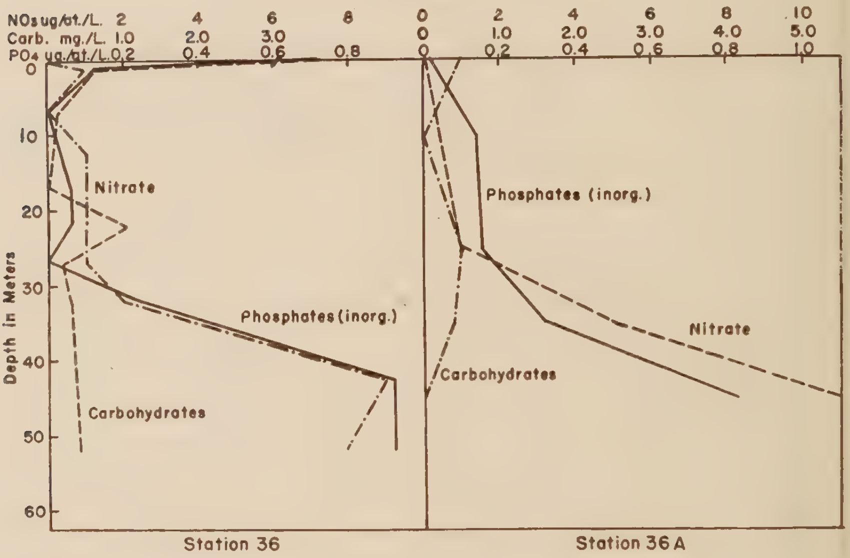


the minimum coming about 1 o'clock in the morning and the maximum in mid-afternoon.

On one of our routine cruises in the Gulf of Mexico a bloom of microorganisms was encountered and some detailed studies were made. Figure 1 shows the vertical distribution of the carbohydrates and other factors as they occurred in the bloom and just at its edge. The bloom was mainly composed of an unidentified ciliate.

The research vessel *Alaska* is equipped with an automatic plankton sampler which was designed to sample copepod populations continuously in hourly components. Figure 2 illustrates the hourly variations or carbohydrates and other chemical parameters sampled simultaneously with the hourly fractions of the plankton sampler. There are a number of important implications here that do not fall within the

FIGURE 2



scope of this discussion, but the point to be demonstrated is the type of distribution to be expected and how it fits in with the idea of patchiness in plankton distributions. The area in which the chemical factor showed pronounced maxima is biologically distinct from that in which they are at their minima.

Tyrosine and tryptophane. These amino acids are being determined routinely on all oceanographic stations occupied by the *Alaska* and their vertical and horizontal distributions studied in relation to the plankton community. We cannot, of course, say that the values we get for these represent amino acids in solution, because they may indicate the presence of intact proteins from which we get the acids on hydrolysis. The important thing is that we find measurable quantities which may represent up to 50 mg. of protein per liter if tyrosine is taken as 4 per cent of a protein molecule.

Rhamnoside. This sugar complex has been isolated (Wangersky, 1952) and concentrated in crystalline form in a number of instances from tidal marshes, open ocean, and more recently from the Florida red tide of November, 1952. In the latter case it was extracted at the rate of 50 mg. of crystalline material per liter of water. We have no routine test for this material, and, as yet, are not sure of its chemical structure.

Ascorbic acid. Minute quantities of this compound were isolated and identified spectrometrically (Wangersky, *loc. cit.*). It is only to be expected that this and other vitamins would be in sea water which is supporting a great amount of activity, both plant and animal.

Unidentified compounds. In the course of this work a number of distinct fractions have been isolated chromatographically and await chemical identification and testing for biological activity. Among these are some relatively abundant substances which appear to be carbohydrate derivatives of low molecular weight (two or three carbon atoms). These are particularly interesting because some of their characteristics fit in the pattern of the N-ethyl-carbazol substances mentioned above.

In the bottom sediments from the Gulf of Mexico taken at 1,700 fathoms we have found yellow lipoid materials which give a bluish fluorescence under ultraviolet light. These may or may not be related to the substances mentioned by Kalle (*loc. cit.*).

THE SIGNIFICANCE OF THE COMPOUNDS IN THE MARINE COMMUNITY

1. As energy source.

As already mentioned, much of the interest in this subject has been in the nature of controversy regarding Pütter's theory. It is entirely possible that at least some organic materials are adsorbed on inert particles and then ingested to be stripped, as it were, for easy assimilation by the organisms. We are particularly interested in investigating the possibility of using this mechanism in the rearing of very young fish.

2. As growth promoters and inhibitors.

This may well be the field in which dissolved organic compounds have their greatest significance. The importance of the micro-biota in the marine economy needs no emphasis. Neither is it necessary to emphasize the fact that a great proportion of this segment of marine life derives its nourishment from the utilization of dissolved substances. If growth-promoting substances are found to be necessary in experimental nutrient solutions used in the culture of various planktonic organisms, it is likely that they will also be required in a normal environment. For instance, it has been found that several planktonic organisms will not flourish without the addition of soil extract to the artificial media used in their culture (Sweeney, 1951). Hutner and Provasoli (1951) reflect that ''A mud or soil with an abundant and varied microflora should contain very nearly the gamut of microbial metabolites; . . .'' Lake drainage, tidal marsh and estuarial effluents can all be considered as soil extracts which have been manufactured on a grand scale.

Once enriched by an organic bearing land effluent, some sea areas establish their own milieu which, in turn, evidently can produce growth promoting substances of their own. Large over-blooms of dinoflagellates must have their origin in something of this sort.

We plan to try some of the substances that have been isolated from such blooms and purified in our laboratories as growth promoters on young fish, as well as on various microorganisms, particularly the dinoflagellates associated with the Florida red tide.

Another candidate for significance in this area would be the caretenoid residues from the phytoplankton. These can be found in both sediments and water columns in extractable quantities and their influence on the marine fauna, micro and macro, should most certainly be given detailed attention.

Metabolites can limit populations as well as assist their proliferation. Pratt (1943) found that a water soluble extract from old cells of *Chlorella Vulgaris* retarded photosynthesis in young cells. He improved the growth of his cultures by providing means of removing these metabolites. The importance of the study of such compounds in connection with phytoplankton blooms is obvious.

3. As regulators of feeding activity.

Collier *et al.* (*loc. cit.* in press) have demonstrated the relationships existing between unknown ''carbohydrate'' compounds (N-ethylcarbazol substances) and the filtration rate of oysters. There appeared to be a threshold beneath which the oysters would not pump water, but above which there was a quantitative association. More carbohydrates seemed to be required when the water temperatures were higher. The oysters exhibited testing periods during which the valves opened only to a certain point, and beyond which they would not open unless the carbohydrates were at threshold level or over. This testing was at random, and at times periods of high carbohydrate would be allowed to pass undetected because the oyster failed to make a test opening. It is possible that this mechanism serves to keep the oyster from expending stored energy on pumping sterile water.

4. Effects on the movements of animals.

An extension of the above effects of organic compounds on oysters could be made into the field of fish behavior. If oysters have the neurosensory systems capable of detecting and acting on such stimuli, there is no reason to think that a similar mechanism could not exist in fish.

Stevens (1949) cites supporting evidence that fish such as mackerel and herring avoid water heavily populated with phytoplankton such as the diatom *Rhizosolenia* or the flagellate *Phaeocystis*. On the other hand he relates that mackerel are caught most in so-called yellow water which is rich in copepods.

A study of the organic compounds exuded into the water by these different populations and the effects of these compounds on fish would certainly be rewarding.

5. As toxins.

We have here only to mention the great fish kills which are laid at the door of large blooms of dinoflagellates of various species. Riegel *et al.* (1949) isolated definite toxins from blooms of *Gonyaulax catenella* which had a toxicity of 1.65 mouse units per microgram. A mouse unit is that quantity of poison which will kill a 20-gram mouse in 15 minutes when injected intraperitoneally.

The author experimentally killed *Fundulus* sp. and *Cyprinodon* sp. with small quantities of water from the November red tide in Florida. This water was quick frozen upon collection and was held in the frozen state for a month before the experiment, and fish were killed in less than 20 minutes by a 4 per cent mixture of this water. The same water held at room temperature from the time of original collection was not toxic. It is hard to avoid the conclusion that this water, in its original state, held in solution some organic compound which acts as a poison to fish and which was stabilized by quick freezing.

6. As aid in evaluating biological activity of discrete water masses.

It appears that some of these compounds might be produced in the early phases of the photosynthetic process, and some in the anabolic phases of a phytoplankton community. In any case, their concentration and distribution would be dependent upon the size of the colony of organisms producing them, the activity level, and the potential productivity of the water supporting the growth. It should be possible, then, to obtain valuable information on the productivity of ocean waters by an analysis of these factors. Such studies could be at the level of short-term variations of activity within patches of plankton by analysis for the more volatile components, while a long-range approach over a greater area could be had through a study of the more stable residues.

SUMMARY

That sea water contains a significant quantity of dissolved organic compounds is a long recognized fact. More recently, biological differences between waters have been proven and their effects on the survival of invertebrate larvae demonstrated. It has been shown that substances which may originate in the photosynthetic process have a direct and quantitative influence on the feeding rate of oysters.

In the laboratories of the Gulf Fishery Investigations of the U. S. Fish and Wildlife Service carbohydrate and proteinaceous substances are being isolated and purified for experimental testing on living organisms, including young fish and dinoflagellates.

The principal fields of possible significance of these compounds are: as an energy source; as regulators or stimulators of feeding activities; effects on movements of marine animals; toxins; and in the evaluation of the biological activity within discrete bodies of water.

LITERATURE CITED

Collier, Albert, Sammy Ray, and Wayne Magnitzky
1950. A preliminary note on naturally occurring organic substances in sea water affecting the feeding of oysters. Science. 111:151-152.

Collier, Albert, Sammy Ray, Wayne Magnitzky, and J. O. Bell
In press. On the existence of dissolved organic substances in sea water and their effect on the activity of oysters.

Cooper, L. H. N.
1951. Chemical properties of the sea water in the neighborhood of the Labadie Bank. Jour. Mar. Biol. Assn. U. K. 30:21-26.

Fox, Denis L.
1950. Comparative metabolism of organic detritus by inshore animals. Ecology. 31: 100-108.

Fox, Denis L., J. D. Isaacs, and E. F. Corcoran
1952. Marine leptopel, its recovery, measurement and distribution. Jour. Mar. Res. 11:29-45.

Goldberg, E. D., Marjorie Barker, and D. L. Fox
1952. Microfiltration in oceanographic research. I. Marine sampling with the molecular filter. Jour. Mar. Res. 11:194-204.

Hutner, S. H., and Luigi Provasoli
1951. The Phytoflagellates. Biochemistry and Physiology of Protozoa. Vol. I, pages 27-128. Edited by André Lwoff. Academic Press. New York.

Jørgenson, C. Barker
1952. On the relation between water transport and food requirements in some marine filter feeding invertebrates. Biol. Bull. 103:356-363.

Kalle, Kurt
1949. Fluoreszenz und Gelbstoff im Bottnischen und Finnischen Meerbusen. Deut. Hydro. Zeitsch. 2:117-124.

Lucas, C. E.
1949. External metabolites and ecological adaptation. Symp. Soc. Exp. Biol. No. III, Growth, pages 336-356.

Pratt, Robertson
1943. Studies on *Chlorella Vulgaris*. VI. Retardation of photosynthesis by a growth-inhibiting substance from *Chlorella Vulgaris*. Amer. Jour. Bot. 30:32-33.

Pütter, A.
1909. Die Ernährung der Wassertiere und der Stoffhaushalt der Gewässer. Gustav Fischer, Jena.

Riegel, Byron D., Warren Stanger, Donald M. Wikholm, James D. Mold, and Hermann Sommer
1949. Paralytic shellfish poison. V. The primary source of the poison, the marine plankton organism, *Gonyaulax catenella*. Jour. Biol. Chem. 177:7-11.

Steven, G. A.
1949. Contributions to the biology of the mackerel *Scomber Scombrus* L. II. A study of the fishery in the southwest of England, with special reference to spawning, feeding, and "fishermen's signs." Jour. Mar. Biol. Assoc. U. K. 28:555-581.

Sweeney, Beatrice Marcy
1951. Culture of the dinoflagellate *Gymnodinium* with soil extract. Amer. Jour. Botany. 38:669-677.

Wangersky, Peter J.
1952. Isolation of ascorbic acid and rhamnosides from sea water. Science. 115:685.

Wilson, Douglas P.
1951. A biological difference between natural sea waters. Jour. Mar. Biol. Assn. U. K. 30:1-20.

Wilson, Douglas P., and F. A. J. Armstrong
1952. Further experiments on biological differences between natural sea waters. Jour. Mar. Bio. Assn. U. K. 31:335-349.

DISCUSSION

DR. MCHUGH: One of the chief criticisms of the conventional method of measuring productivity of the sea has always been the fact that what you were measuring is really a standing crop rather than the total amount of potential productivity of the area.

I think this work of Mr. Collier's has great promise of perhaps bypassing that difficulty; also, as he pointed out toward the end of his paper, these substances are supposedly uniformly distributed throughout the water mass, rather than occurring in chunks as plankton does. We will look forward to the development of this work with interest, I am sure.

I am sure some of us must have some questions to ask Mr. Collier in regard to his methods and to the possibility of utilizing his work for these various purposes he has described.

CHAIRMAN HUBBS: I would like to ask Mr. Collier a point which he did not bring out particularly, whether he is inclined to believe that these sugars or other dissolved materials of that sort are actually utilized by the fish by being absorbed through the gills and utilized in the nutrition of the fish?

MR. COLLIER: I am afraid, Dr. Hubbs, in this case, I might have to resort to the work on oysters; I hope I might be forgiven for that. We did measure the removal of the carbohydrate substances from the sea water by the oyster in our work, and we found it was removed as the water passed through the oyster. We are not prepared to say that this was actually utilized by the oyster physiologically because it is entirely possible that the material might have been absorbed on mucous train and voided with the feces, rather than being ingested. There is, of course, in the literature now a rather increasing amount of evidence that these compounds, after all, might be absorbed by organisms from a solution of water.

CHAIRMAN HUBBS: Even if the concentrations were fine in the sea water? I think that is one criticism we have always put to the old belief that these materials were significant.

MR. COLLIER: Do I gather that you mean the amounts present in sea water would not be sufficient to support an organism?

CHAIRMAN HUBBS: Either that or that they would not utilize it at that concentration.

MR. COLLIER: Well, of course, that would depend on the size of the organism, its body surface and so on, the demand of the organism for such substances, and whether you would take the point of view that the organism would survive on these substances.

It is entirely possible that, even at low concentrations, they might provide for supplements to the field.

CHAIRMAN HUBBS: Have you in mind any investigations with radioactive material to determine if the material or organic matter actually finds a place in the oyster or fish?

MR. COLLIER: No, sir, not in the immediate future. Of course, we realize the value of that particular technique and that is being used in certain cases by another laboratory of the Service. We have considered that; but, in our laboratory, we do not have the facilities and it is not in sight.

DR. HUGH BENNETT: I just wanted to ask if these organic substances are in complete solution or possibly some of them in some such state as colloidal suspension.

MR. COLLIER: In our work, we did run water through bacteriological filters; but, of course, that does not mean that we might not have had some very fine colloidal suspensions. It all depends on whether you want to establish the boundary.

DR. MCHUGH: I would like to ask just one more question. That is, you have shown that these substances have some effect on the feeding activities of the oysters. I wonder if you have considered any work on the possibility of their having an effect on the spawning activities of oysters and other mollusks.

MR. COLLIER: We have not studied them in relation to spawning activities. Of course, we all know of Nelson's work with the hormone, dianaline. That is something produced by the oyster itself. We have not gone into this, after all.

CHAIRMAN HUBBS: In partial answer to Dr. Bennett's question, I might say that we have research going on at the Scripps Institution of Oceanography, which indicates that the particular organic material in the sea, the remains of the organisms, some of which is in virtually colloidal state, is probably of tremendous significance in the nutrition of the filter-feeding organisms, such as the mussel and oyster, and a great many others. Some of our men there in biochemistry feel that this sort of material is probably more significant in many places, and at many times, than the actual living plankton itself.

Dr. McHugh: If there is no more discussion of this paper, I will turn the floor back again to Dr. Hubbs.

Chairman Hubbs: We now have a bit of shift in our line of papers here, from those dealing with the fishery products and the organic materials which are basic thereto, to a series of papers on marine mammals, a subject which I know will be of very great interest to all of us.

The first of these papers is by Richard E. Griffith, of the Fish and Wildlife Service, dealing with the future of the sea otter.

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ON FOOD AND FEEDING OF LARVAE OF THE AMERICAN OYSTER, C. VIRGINICA

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Feeding experiments have shown that larvae of the American oyster, *Crassostrea virginica,* are limited as to the types of food they can utilize, by factors other than the size of the micro-organism or particle. We have previously reported four species of marine bacteria and three species of flagellates that had no effect on the rate of growth of oyster larvae (Davis, 1950a). In one experiment, for example, in cultures that received sulfur bacteria as food, the larvae averaged only 94.05 μ in length at 14 days, a size not significantly different from that of larvae in unfed control cultures. Moreover, it was an increase of only about 20 μ over the initial size of early straight-hinged larvae which usually measure about 74–76 μ in length. In a pair of parallel cultures fed mixed phytoplankton composed chiefly of Chlorella, the larvae averaged 140.75 μ in length by the 14th day or had gained about 65 μ over their initial size.

The same series of experiments also showed that marine detritus, which we had collected from several sources, was not utilized by the larvae, and that organic media added to the larval cultures caused no increase in the rate of growth of the larvae.

On the basis of the above experiments it was reported (Davis, 1950a) that our mass culture of green phytoplankton consisting chiefly of Chlorella, which we shall refer to as "mixed Chlorella," was the best food for oyster larvae then available. It did not consistently induce a good rate of growth when fed to larvae during their earlier stages, but once the larvae had attained a size of approximately 125 μ they appeared to utilize the "mixed Chlorella" quite readily.

In the feeding experiments on oyster larvae reported in the following pages, we have tested nine additional species of marine bacteria, isolated from the mud of Milford Harbor by Dr. Burkholder of Yale University; six more species of marine flagellates, including some of the same varieties used by Bruce, Knight and Parke (1940), obtained from Dr. Russell of the Plymouth Laboratory, England; and a bacteria-free culture of *Chlorella* sp. isolated from our mixed phytoplankton culture by Dr. Ralph Lewin of Yale University. These feeding experiments were conducted during the winter and early spring using oysters brought to spawning condition by the method described by Loosanoff (1945) and by Loosanoff and Davis (1952).

To insure uniformity in size, quality, and number of larvae in the different culture jars of a series, at the beginning of an experiment, and except for foods, to provide as nearly equal treatment of all cultures as possible, the following procedure has been made standard practice.

To obtain fertilized eggs, the conditioned oysters were placed in spawning dishes, filled with sea water that had been filtered through cotton to remove debris and most planktonic forms, and spawning was induced by adding small quantities of sperm suspension and raising the temperature to about 30.0° C. The eggs of *C. virginica,* because of their small size, cannot readily be separated from excess sperm, as can those of *Venus mercenaria* (Loosanoff and Davis, 1950). The spawning females were, therefore, separated from the males and placed in spawning dishes containing only a slight excess of sperm.

The fertilized eggs were collected in a tall narrow jar by screening the contents of the spawning dishes through stainless steel screens having 100 meshes per inch. This screen allowed the fertilized eggs to pass through unharmed but retained larger debris and feces expelled by the oysters during spawning. Since we wished to have 5000 larvae per liter in our experimental cultures, the egg suspension in the tall narrow jar was thoroughly stirred with a perforated plastic plunger to insure uniform distribution of the eggs and a sample was withdrawn and the number of fertilized eggs per ml. determined.

Only rarely did 100 per cent of the fertilized eggs develop into normal straight-hinged veliger larvae, but if less than 50 per cent developed normally, we discarded the larvae. It became our practice, therefore, to introduce enough fertilized eggs into each culture jar to give approximately twice the desired number of larvae if all the eggs should develop normally, *i.e.,* about 10,000 fertilized eggs per liter. The 20-liter earthenware culture jars were then filled with cotton-filtered sea water and the eggs permitted to develop for 48 hours with no supplemental feeding.

After 48 hours the veliger larvae, fully protected by their shells, were collected by passing the contents of each culture jar through a 325-mesh stainless steel screen. The screen retained the shelled veligers but permitted undeveloped eggs, and embryos that had not progressed to the shelled stage, to pass through. The normal larvae from all culture jars were thus collected and pooled in 4 to 7 liters of sea water in a tall narrow jar. After thoroughly mixing the contents of this jar with a perforated plastic plunger, to obtain a uniform distribution of the larvae, a sample was withdrawn and the number of larvae in one ml. of the pooled culture determined. By keeping the pooled culture thoroughly mixed, with the larvae uniformly suspended, and taking appropriate volumes, the desired number of larvae could be introduced into each culture. The larvae of all cultures were, therefore, closely comparable in size and quality, as well as number, when the different food treatments were started on the second day.

All culture jars were kept covered so they were uniformly dark and all were in a common water bath. Although the temperature of the water bath fluctuated between 21.0° and 23.0° C. all cultures were equally affected. The sea water in all cultures was replaced with fresh cotton-filtered sea water every second day (Loosanoff and Davis, 1950).

Neither aeration nor mechanical agitation is necessary for normal development of oyster larvae when the water is changed every second day. We did not, therefore, use either aeration or mechanical agitation in these experiments as it is difficult to insure equality of such treatments in a series of cultures.

Samples were taken whenever desired by first washing the entire contents of a culture jar onto the 325-mesh screen, then re-suspending the larvae in 1000 ml. of sea water in a parallel-sided graduated cylinder. To insure uniform distribution of the larvae, the contents of the cylinder were thoroughly mixed with a perforated plastic plunger and a one-, two- or five-cc. sample was withdrawn and preserved. All the larvae in a sample were transferred to a Sedgwick-Rafter cell and examined under a compound microscope. Larvae that were living at the time the sample was taken could thus be identified and counted to determine the per cent surviving and a random sample of 100 of these larvae was measured to obtain growth data.

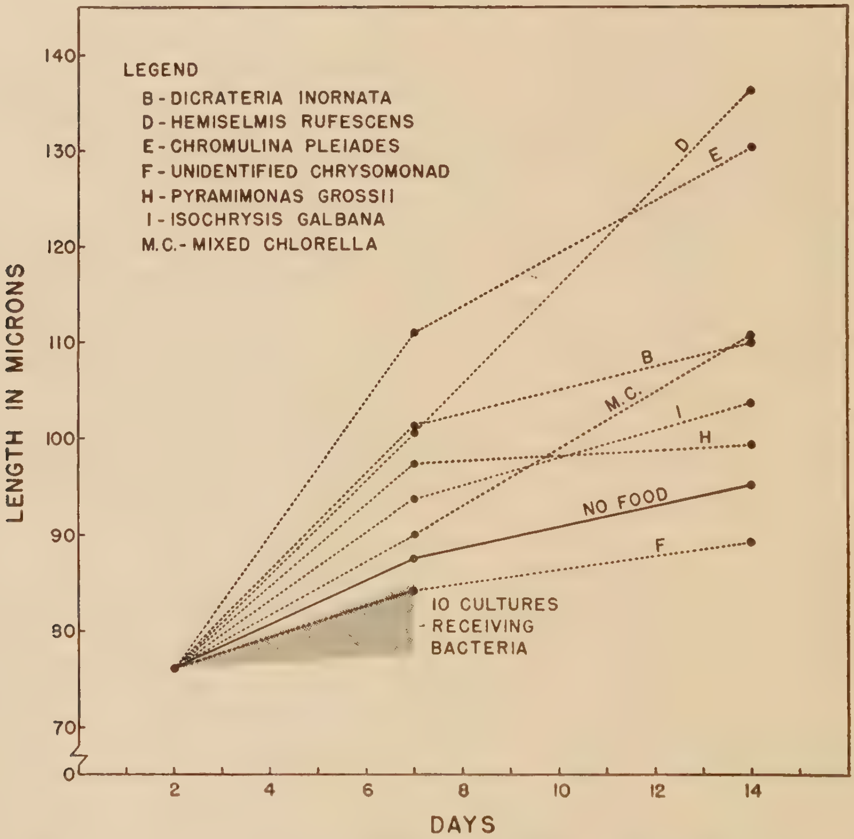

FIGURE 1. Growth of larvae of *C. virginica* fed different foods. Each point on a curve represents the mean length of 100 larvae. Flagellates D, E, and I were fed at the rate of 10,000 per ml./day. Flagellates H and F were fed at the rate of 5000 per ml./day. Flagellate B was fed at the rate of 10,000 per ml./day for first seven days and 5000 per ml./day thereafter.

Eighteen parallel cultures were used in the first of the present series of experiments. Each of the first nine received a different species of the marine bacteria isolated by Dr. Burkholder, six of the remaining each received a different species of the marine flagellates received from England, one received *B. coli* plus a bacteriophage, one received our "mixed Chlorella" and the final culture, which received no supplemental food, served as the control.

The larvae in all ten cultures receiving bacteria and those in the culture receiving flagellate F, an unidentified chrysomonad, grew less rapidly than did those in the unfed control culture (Fig. 1). Moreover, in the ten cultures receiving bacteria, the larvae were all dead by the eleventh day. We can assume that these bacteria and flagellate F were not utilized.

In the remaining six cultures that received supplemental food, the larvae grew more rapidly than did those in the unfed control. We can conclude, therefore, that oyster larvae probably do utilize the five species of flagellates, *Dicrateria inornata, Chromulina pleiades, Hemiselmis rufescens, Isochrysis galbana* and *Pyramimonas grossii,* as well as our "mixed Chlorella."

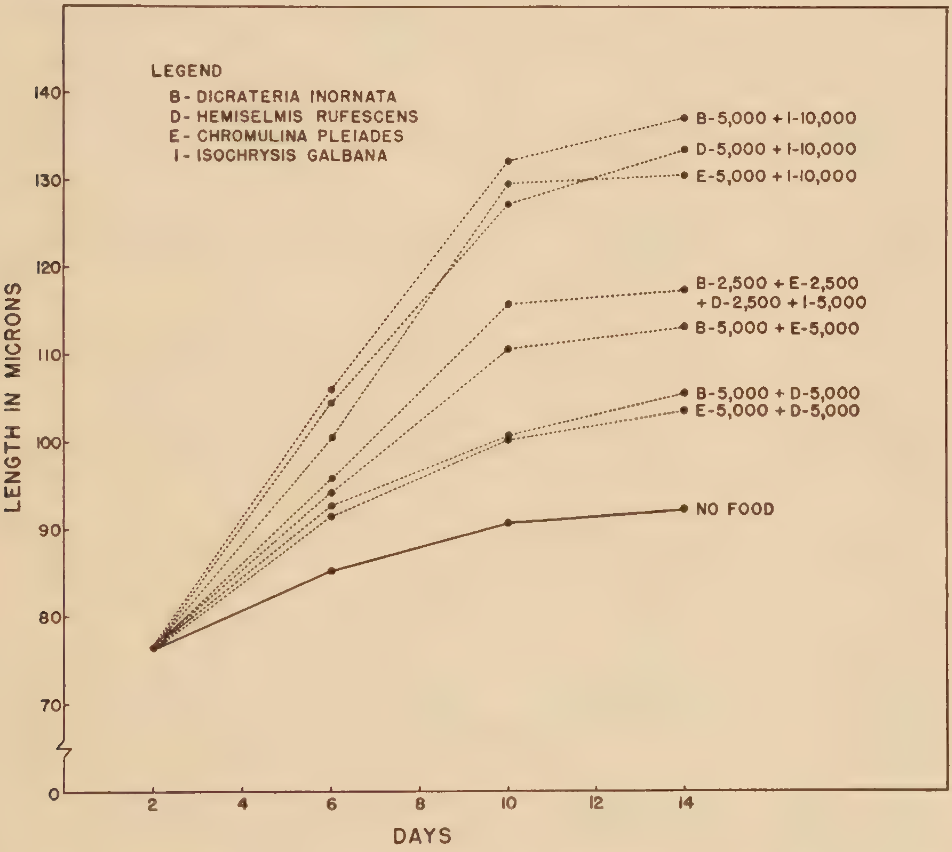

FIGURE 2. Growth of larvae of *C. virginica* fed combinations of flagellates. Each point on a curve represents the mean length of 100 larvae from each of duplicate cultures. Numbers following letter designation of flagellates indicate rate of feeding in number of flagellates per ml./day.

Unfortunately, due to difficulties in mass production of the flagellates, we were not able to feed equal numbers of each flagellate nor were we able to keep the rate of feeding constant in the larval culture receiving flagellate B (Dicrateria).

In this culture Dicrateria was added at the rate of 10,000 cells per ml./day for the first seven days but after that it was necessary to reduce the rate to 5000 cells per ml./day.

Flagellate I (Isochrysis) and flagellate D (Hemiselmis) were added at the rate of 10,000 cells per ml./day throughout the experiment, while flagellates F (the unidentified chrysomonad) and H (Pyramimonas) were added at the rate of 5000 cells per ml./day. Moreover, since this was a preliminary experiment, single cultures were used and the results are consequently less reliable than in later experiments where duplicate or triplicate cultures were used to test each food. Isochrysis, for example, appears to be a comparatively much poorer food here than it proved to be in later experiments. Note that the larvae fed "mixed Chlorella" and those fed flagellate D (Hemiselmis) grew slightly faster after the

TABLE I

Mean length of larvae (in microns), receiving different food treatments, at 6, 10 and 14 days with growth increments calculated as mean length minus mean length of 2-day-old larvae (76.5μ)

Food treatment	Mean length 6 days	Growth increment 2–6 days	Mean growth increment	Mean length 10 days	Growth increment 2–10 days	Mean growth increment	Mean length 14 days	Growth increment 2–14 days	Mean growth increment
No food									
Culture No. 1	85.90	9.40		92.40	15.90		93.25	16.75	
Culture No. 2	84.60	8.10	8.750	89.30	12.80	14.350	91.35	14.85	15.800
B+E									
Culture No. 1	95.60	19.10		112.20	35.70		113.35	36.85	
Culture No. 2	92.75	16.75	17.925	109.35	32.85	34.275	113.30	36.80	36.825
B+D									
Culture No. 1	93.80	17.30		100.60	24.10		102.83	26.35	
Culture No. 2	91.85	15.35	16.325	100.75	24.25	24.175	108.50	32.00	29.175
B+I									
Culture No. 1	106.65	30.15		133.75	57.25		139.60	63.10	
Culture No. 2	105.40	28.90	29.525	130.55	54.05	55.650	134.75	58.25	60.675
E+D									
Culture No. 1	91.95	15.45		99.25	22.75		103.70	27.20	
Culture No. 2	90.85	14.35	14.900	101.70	25.20	23.975	103.95	27.45	27.325
E+I									
Culture No. 1	98.65	22.15		127.10	50.60		129.95	53.45	
Culture No. 2	102.35	25.85	24.000	132.25	55.75	53.175	131.35	54.85	54.150
D+I									
Culture No. 1	104.30	27.80		125.00	48.50		131.20	54.70	
Culture No. 2	104.95	28.45	28.125	129.40	52.90	50.700	135.75	59.25	56.975
B+E+D+I									
Culture No. 1	94.75	18.25		116.05	39.55		116.90	40.40	
Culture No. 2	97.05	20.55	19.400	114.70	38.20	38.875	117.75	41.25	40.825

seventh day, while those receiving other foods grew somewhat less rapidly the second week (Fig. 1). This may indicate that these two forms are more readily utilized by the larvae in the later stages of development.

Subsequently, in experiments of factorial design, we have fed oyster larvae various combinations of those flagellates which the previous experiment had shown the larvae could utilize. We hoped to estimate the relative value of the different flagellates as foods for oyster larvae, and to determine whether some combination of them might provide a more balanced diet which would result in more rapid larval growth.

The results of a typical experiment of this kind show that certain combinations did appear to give more rapid growth of larvae than others (Fig. 2). The combination of the flagellates B + E, for example, gave more rapid growth than either the combination B + D or E + D. Nevertheless, the greatest differences are correlated with the total number of flagellates given per day. Thus, the three combinations B + I, D + I, or E + I, each consisting of a total of 15,000 flagellates per ml./day gave definitely more rapid growth than did the combination B + E + D + I which consisted of a total of only 12,500 cells per ml./day. Moreover, this latter combination in turn gave slightly more rapid growth than did any of those combinations consisting of only 10,000 flagellates per ml./day. Thus, the total number of flagellates added appears to be an important factor and suggests that the different species of flagellates may be of nearly equal value as foods for oyster larvae.

TABLE II

Ratios of the mean growth increments, due to each food combination, to the mean growth increments of larvae in the unfed control cultures. (Standard error of averages 3.75%)

Days	No food	B+E	B+D	B+I	E+D	E+I	D+I	B+E+D+I
2–6	1	2.049	1.866	3.374	1.703	2.743	3.214	2.217
2–10	1	2.389	1.685	3.878	1.671	3.706	3.533	2.709
2–14	1	2.331	1.847	3.840	1.729	3.427	3.606	2.584
Average	1	2.256	1.799	3.697	1.701	3.292	3.451	2.503

Statistical tests showed that the differences in rate of larval growth, attributable to differences in the total number of flagellates present, were indeed significant. Nevertheless, to account completely for the results observed it is also necessary to assume that the different species of flagellates were not of equal value as foods for oyster larvae.

An analysis of variance of the growth increments (Table I) showed that the average difference between growth increments of duplicate cultures was not significant. We are justified, therefore, in using the ratio of the mean growth increments of the duplicate cultures as a relative measure of the efficiency of the different foods. Dividing the mean growth increments for each period by the mean growth increment of the unfed cultures for the same period gives relatively constant ratios (Table II). An analysis of variance showed that differences between the ratios for the 2–6-, 2–10- and 2–14-day periods were not significant. The average ratio can be used, therefore, as a numerical estimate of the relative over-all efficiency of the different food combinations at the particular concentrations used in this experiment.

This suggests that if the effect on growth of larvae on any given food really is constant, the uncontrolled factors responsible for the growth of unfed cultures have a multiplicative power on the effect of the different food combinations. If we postulate, in addition, that the effect of each species of flagellate is proportional to its concentration and independent of the presence or absence of other foods, we can formulate the following equation for the growth increment (Y) of any combination of foods: $Y = k\ (1 + b + e + \ldots)$, where k is the uncontrolled variable responsible for the growth of unfed cultures and b, e, . . . are the effects of the foods B, E, etc. Thus, if b is the effect of 2500 *B* (Dicrateria) per cc., e is the effect of 2500 E (Chromulina) per cc., d is the effect of 2500 D (Hemiselmis) per cc. and i is the effect of 5000 I (Isochrysis) per cc., the equation for the growth increment of the food combination $B + E + D + I$ becomes $Y = k\ (1 + b + e + d + i)$, while for the combination $B + E$, in this experiment it becomes $Y = k\ (1 + 2b + 2e)$ and for the unfed cultures is $Y = k\ (1 + 0)$ or $Y = k$. From the design of the experiment and having a value for k (the observed growth increment of unfed cultures) we can calculate values for b, e, d and i using the values given for the food combinations in the average ratio (Table II). Thus b, the effect of 2500 Dicrateria per cc., becomes: $b = 1/7\{[(2.256–1) + (1.799–1) + (3.697–1) + (2.503–1)] – 3/4[(1.701–1) + (3.292–1) + (3.451–1)]\}$ or $b = 1/7(6.255–4.083) = 0.3103$.

Similarly, the separate effects of the other flagellates become $e = 0.185$, $d = 0.110$, and $i = 0.982$, but this ratio compares 2500 of each B, E and D with 5000 of I. When all are adjusted to the 10,000 level so that we compare the flagellates cell for cell, they become $b = 1.240$, $e = 0.740$, $d = 0.440$ and $i = 1.964$. Since these values were taken from the average ratio of the food combinations, the values represent the over-all efficiency of the foods throughout the experiment.

Similar ratios or estimates of food values can be worked out for the separate four-day periods; corrected by successive approximations and adjusted to the 10,000 level for each flagellate they are:

	b	e	d	i
2–6 days	1.372	0.788	0.776	1.716
6–10 days	1.616	1.112	−0.820	3.226
10–14 days	3.776	−2.504	5.123	0.450

The value of most of the flagellates varies considerably. These variations probably represent day-to-day fluctuations in both physiological state and purity of the flagellate cultures used as foods, for it is known that in many micro-organisms the chemical composition varies with their physiological condition. Thus, although B (Dicrateria), in this experiment, appears to be a better food than E (Chromulina) in approximately 50 per cent of the experiments of this series the reverse is true. It seems probable, therefore, that differences in rate of growth of oyster larvae brought about by variations in the physiological condition of Chromulina and Dicrateria are as great or greater than differences dependent upon which of these two species the oyster larvae are fed.

Flagellate D (Hemiselmis) appears to be the poorest of these four species. However, the high value for the 10–14-day period may indicate, as in the previous experiment, that Hemiselmis is more readily utilized by older larvae. Unfortunately, this flagellate culture was lost and we could not obtain further data on its effect on the rate of growth of oyster larvae.

Bruce, Knight and Parke (1940), in feeding experiments on larvae of the European oyster, *Ostrea edulis,* rated flagellate I as a "good to very good" food while rating flagellate B as "fair." Although their tabulated data seem to indicate that flagellate F was utilized and that flagellate D was not, the authors do not discuss these two flagellates further.

The second part of the problem was to determine whether, by combining the various flagellates, we could provide a diet that would bring about more rapid growth of oyster larvae than could be obtained by feeding an equivalent number of cells of a single species. From a statistical viewpoint, if the separate growth increments due to the different foods, as calculated above, can be combined according to the formula to give a satisfactory fit to the growth increment observed when these foods are used in combination, we will have no reason to believe that there are interactions. In other words, if the effect of B and the effect of E can be added together as in the formula to give a growth increment that agrees closely with that observed when B and E were fed in combination, we will have no reason to believe that the combination B + E is any better as a food than equivalent quantities of B or E alone.

TABLE III

Differences between observed and calculated mean lengths of oyster larvae receiving different foods

Foods	6 days			10 days			14 days		
	Observed	Calculated	Diff.	Observed	Calculated	Diff.	Observed	Calculated	Diff.
No food	85.2	84.8	−0.4	90.9	90.9	0.0	92.3	92.3	0.0
B+E	94.2	93.7	−0.5	110.2	110.3	+0.1	113.3	113.2	−0.1
B+D	92.8	93.7	+0.9	100.7	100.7	0.0	105.7	108.8	+3.1
B+I	106.0	104.7	−1.3	132.2	134.3	+2.1	137.2	137.1	−0.1
E+D	91.4	91.3	−0.1	100.5	100.6	+0.1	103.8	103.9	+0.1
E+I	100.5	102.3	+1.8	129.7	130.2	+0.5	130.7	130.0	−0.7
D+I	104.6	102.2	−2.4	127.2	126.1	−1.1	133.5	133.2	−0.3
B+E+D+I	95.9	98.0	+2.1	115.4	114.7	−0.7	117.3	119.6	+2.3

A statistical analysis of the results of the previous experiment shows no evidence that any of the combinations of flagellates tested results in more rapid growth of oyster larvae than would equivalent amounts of any of the flagellates separately. The observed mean lengths of larvae, receiving combinations of the different flagellates as foods, were compared with the mean length calculated from the values of the separate foods given above as the sum of the growth increment given by the formula plus the mean length of larvae in the unfed control cultures (Table III). At six days the maximum difference between observed and calculated mean length is 2.4 μ, at 10 days it is 2.1 μ, and at 14 days it is 3.1 μ. These differences are of the same order of magnitude as differences between parallel cultures receiving the same treatment and it can be shown that the fit between calculated and observed mean lengths is satisfactory. Therefore, we have no reason to believe that the foods are not completely additive, and no interaction is indicated. Bruce, Knight and Parke (1940) believed that a combination of the flagellates H and I

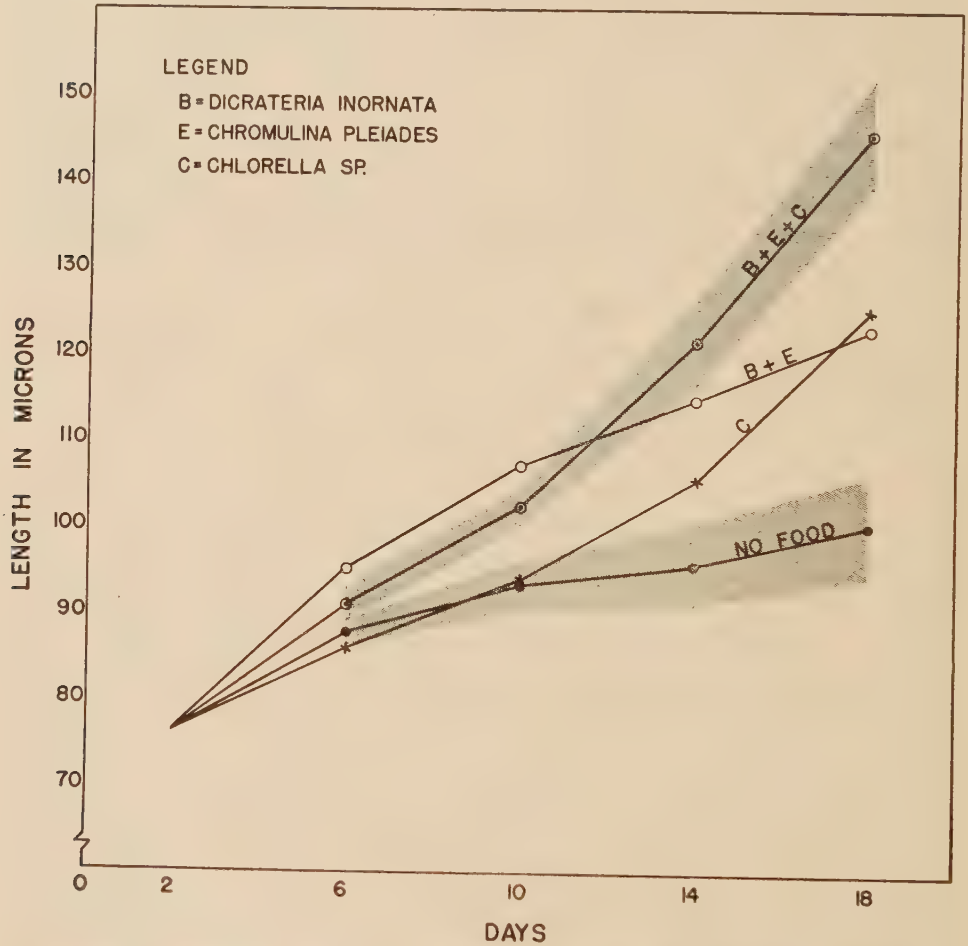

FIGURE 3. Growth of larvae of *C. virginica* fed *Chlorella* sp. alone and in combination with flagellates. Each point on a curve represents the mean length of 100 larvae from each of triplicate cultures. Shaded areas represent 95 per cent confidence bands. Flagellates B and E fed at the rate of 5000 per ml./day and *Chlorella* sp. fed at the rate of 50,000 per ml./day.

was especially suitable as food for larvae of *O. edulis* but did not test for an interaction. Thus far we have not tested this combination with larvae of *C. virginica.*

Studies to determine what concentration of any single species of these flagellates would be required to induce the maximum rate of growth of oyster larvae are still in progress. Preliminary tests indicate, however, with Dicrateria alone as the supplementary food, that this flagellate must be fed at the rate of 25,000 cells per ml./day (the highest rate tested), or higher, to produce the most rapid growth of larvae possible in cultures such as ours, which contain approximately 5000 larvae per liter. Isochrysis has not been tested in varying concentrations, but the larvae grew rapidly when this flagellate was fed at the rate of 20,000 cells per ml./day. When Chromulina was used as the supplemental food, however, the larvae grew slightly faster in cultures receiving 15,000 cells per ml./day than in cultures receiving 20,000 cells per ml./day.

Our experiments indicate, therefore, that while the concentration of flagellates required to give the most rapid growth of larvae probably varies with the species of flagellate, none of the flagellates that were utilizable gave toxic effects when added to our larval cultures at rates up to 15,000 cells per ml./day and for certain species up to 25,000 cells per ml./day. Korringa (1949), on the other hand, although he obtained good growth of larvae and a heavy spatfall of *O. edulis* in his 1947 experiments with concentrations of flagellates between 10,000 and 20,000 per ml., concluded from later experiments that (p. 4) "water initially containing more than 5000 flagellates, or a commensurable great number of other phytoplankton, should be mistrusted as it may contain toxic concentrations of phytoplankton metabolites from the first day the tanks are filled." Imai and Hatanaka (1949) indicate that in culturing larvae of *Crassostrea gigas,* they strive to keep the concentration of the flagellate, *Monas* sp., at a concentration of only 1000 to 2000 per ml. in their cultures. These authors have, at maximum, only about 200 larvae per liter, however, and such low concentrations of flagellates would provide too small a quantity of food to induce appreciable growth of larvae in cultures such as ours with a concentration of approximately 5000 larvae per liter.

In other experiments we sought to determine the effect of the bacteria-free culture of *Chlorella* sp. on the rate of growth of oyster larvae. In these experiments *Chlorella* sp. was tested both alone and in combination with some of the flagellates (Fig. 3). Using triplicate cultures for each treatment, one trio served as a control and received no supplementary food, one trio received *Chlorella* sp. alone (50,000 per ml./day), one trio received a combination of flagellates B + E (5000 per ml./day of each) and one trio received *Chlorella* sp. (50,000 per ml./day) in addition to the combination of flagellates B + E (5000 per ml./day of each).

Our "mixed Chlorella" culture, although apparently being more effectively used by larvae in the later stages of development, had been utilized from the start (Fig. 1). With a pure culture of Chlorella, however, in this and in several repetitions of the experiment, the effect on the growth rate of the larvae during the early stages, although small, is consistently negative (Fig. 3). This is true both when pure Chlorella is added alone, and when it is used in combination with the flagellates. Some time between the sixth and twelfth days, however, the larvae appear to become able to utilize *Chlorella* sp. and it accelerates their growth markedly.

Calculations similar to those previously mentioned give the following values for b, e and c (effect of *Chlorella* sp.):

	b	e	c
2–6 days	0.252	0.329	−0.164
6–10 days	0.191	0.579	0.323
10–14 days	0.598	0.580	2.364
14–18 days	0.620	0.630	3.467

However, when these figures are adjusted to the 10,000 level so that we are comparing food micro-organisms cell for cell, it becomes obvious that Chlorella is inferior to the flagellates as a food on such a basis, thus:

	b	e	c
2–6 days	0.504	0.658	−0.033
6–10 days	0.382	1.158	0.065
10–14 days	1.196	1.160	0.473
14–18 days	1.240	1.260	0.693

Again there is no evidence of an interaction of food organisms and the growth increment of the combination B + E + Chlorella is given by $Y = k(1 + b + e + c)$. These experiments explain our previously published observations (Davis, 1950a) that "mixed Chlorella," while not consistently a good food during earlier larval stages, served quite well as food during later larval stages. The good growth obtained during later larval stages is undoubtedly due to the utilization of Chlorella itself by the oyster larvae. The inconsistency of growth of earlier larval stages is understandable since, from these experiments, we know that during these stages the larvae do not utilize Chlorella. Obviously, then, growth during the early larval stages, when "mixed Chlorella" was used as a food, was due to other forms which might or might not be present at any given time in our mass culture of Chlorella, and to small amounts of food in the sea water, which may, as in the experiment shown in Figure 3, carry the larvae through the early stages until they can utilize Chlorella.

Cole (1936) after a review of the literature on the European oyster (*O. edulis*) states that the conclusion that the larvae are able to develop on Chlorella is not supported by results of well designed critical experiments. Presumably the larvae are unable to digest this alga. We have shown here, however, that Chlorella is utilized by older larvae of *C. virginica* and we have unpublished data showing that larvae of *Ostrea lurida,* a species closely related to *O. edulis,* can be reared to metamorphosis on either mixed Chlorella or a bacteria-free culture of Chlorella.

A number of cultures of *C. gigas* have been reared to metamorphosis (Davis, 1950b) using our "mixed Chlorella" as a food, although in general larvae of this species are similar to larvae of *C. virginica* in being limited as to the types of micro-organisms they can utilize as foods. In addition Loosanoff and Davis (1950), Loosanoff, Miller and Smith (1951), and Loosanoff and Marak (1951) have reared *O. edulis, Venus mercenaria, Mya arenaria* and several other species of lamellibranch larvae using our "mixed Chlorella" as the chief food. Such results certainly indicate that the ability to utilize Chlorella as a food is common to several species of lamellibranch larvae.

In the course of our experiments certain differences in rate of growth of oyster larvae, in different members of a trio or pair of cultures receiving the same treatment, appeared to be due to differences in the number of larvae present in the culture. An experiment in which triplicate cultures at each of four different con-

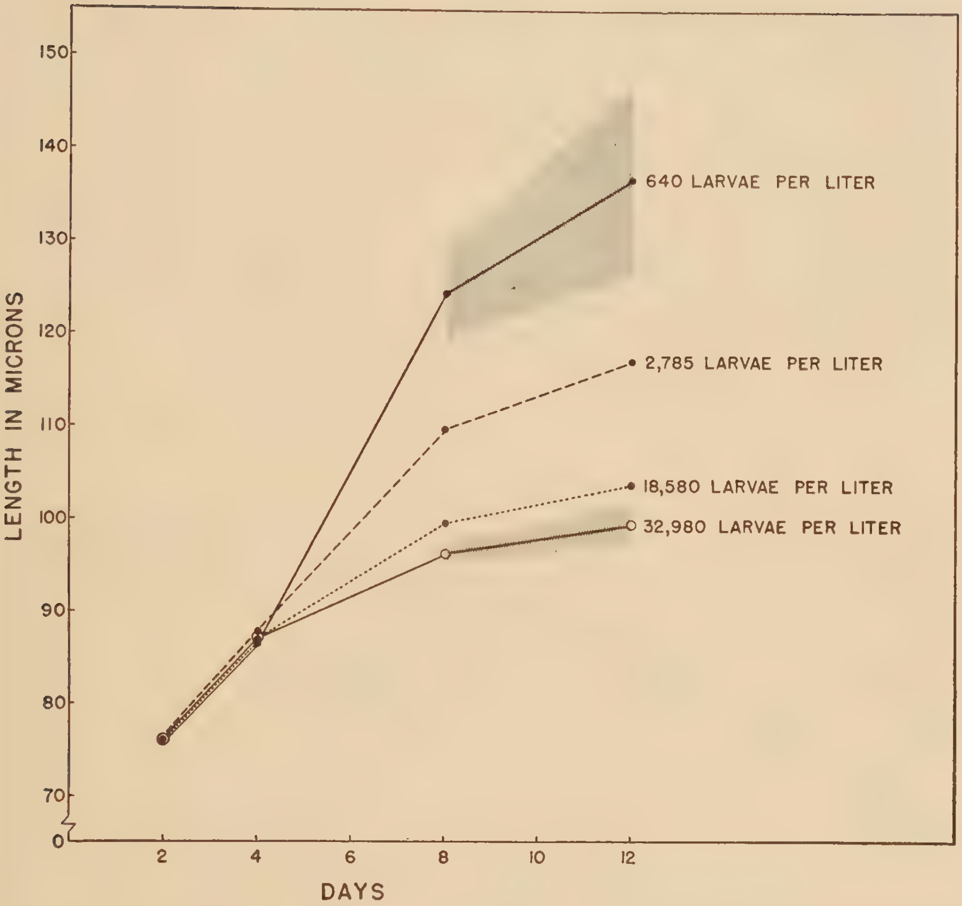

FIGURE 4. Growth of larvae of *C. virginica* cultured at four different concentrations with food constant at 50,000 cells per ml./day. Shaded areas represent 95 per cent confidence bands. Each point on a curve represents the mean length of 100 larvae from each of triplicate cultures.

centrations of larvae were used indicated an inverse relation between the concentration of larvae and their rates of growth (Fig. 4). These cultures all received 50,000 cells per ml./day of our "mixed Chlorella" as a supplementary food.

The between-culture variations, at the two lower concentrations of larvae, were abnormally great, while at the higher concentrations the between-culture variations were normal. Thus at 14 days the average sizes of larvae in the various cultures were as follows:

Number of larvae per liter	Culture number 1	Culture number 2	Culture number 3
640	140.0	140.1	125.17
2,785	110.50	111.57	126.55
18,580	102.65	103.35	105.35
32,980	98.35	98.70	101.60

The 95 per cent confidence bands (Fig. 4) were calculated with the inconsistent values included. We are probably justified in concluding that with all cultures receiving equal quantities of this food, there is an inverse relation between the concentration of larvae in a culture and their rate of growth, at least after the eighth day. The failure of the inverse relation to appear earlier is probably due to the inability of oyster larvae to utilize the "mixed Chlorella" readily during the earlier stages of development.

We do not know whether similar results would be obtained with other foods, but suspect that they would be, nor do we know what results would be obtained if the quantity of food were kept proportional to the concentration of larvae. The results of the experiment suggest, however, that the concentration of larvae in a culture must be considered in comparing rates of larval growth.

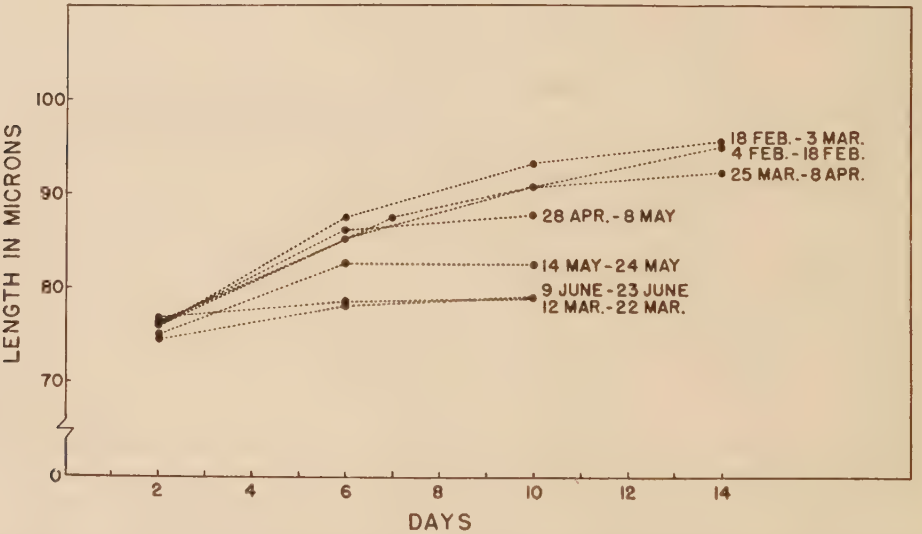

FIGURE 5. Growth curves of unfed control cultures of *C. virginica* larvae showing variations between seven successive experiments. Each point on a curve represents the mean length of 100 larvae from each of duplicate or triplicate cultures.

Other differences, which make comparison of rates of larval growth difficult, are those between successive cultures in which the larvae receive identical treatments. The factor or factors (k) responsible for these differences affect not only the rate of growth of larvae but also, in some experiments, their survival as well. The growth curves of the larvae in the unfed control cultures of seven successive experiments illustrate these differences (Fig. 5). In the 1952 experiments of February 18–March 8 and of February 4–18, the curves appear normal since growth of the larvae in the unfed cultures, although slow, was continuous throughout the 14 days of the experiments. The growth of larvae appears subnormal throughout the May 14–24 experiment, when compared to the above curves, and in the experiments of March 12–22 and June 9–19 almost no growth occurred in these unfed cultures. In the experiment of March 25–April 8 the flattening of the curve between the tenth and fourteenth days, which reflects an almost complete lack of growth of the larvae during this period, appears abnormal. In the experiments of April 28–May 8 and May 14–24, similar abnormal flattening of the growth curves occurred between the sixth and tenth days.

In each of the three experiments in which the flattening of the growth curves of the unfed cultures occurred after the sixth day, there were also seven pairs of cultures receiving different foods, yet all cultures showed similar flattening of their growth curves simultaneously.

This flattening of growth curves cannot be considered a normal deceleration of growth since it is not correlated with either age of larvae (Fig. 5), or with size (Figs. 2 and 5). Moreover, a pronounced simultaneous upswing of growth curves in all cultures was noted in one experiment and minor simultaneous upward trends were noted in several others. Such simultaneous changes in the growth curves of the larvae in all cultures of an experiment, regardless of food treatment, must be a reflection of variation in some unknown factor or factors common to all cultures. The factors common to all cultures, and least susceptible to control, are the physical, chemical and microbiological constituents of the sea water in which the larvae were reared.

Also strongly suggestive of a variation in the physical or chemical constituents of the sea water was the variation in peak densities of flagellate cultures grown in media prepared from sterilized sea water enriched with constant amounts of nutrient salts. Culture media prepared from sea water taken during periods of poor larval growth gave lower peak densities of flagellates than did media made up from sea water taken during periods of good larval growth.

In all of our experiments, in cultures that received flagellates known to be utilizable, the larvae have grown more rapidly than those in the parallel unfed control cultures. Yet we have not been able to overcome completely the effects of the unknown factor (or factors) by supplemental feeding. For example, under the conditions existing during the May 14–24 and June 9–19 experiments, feeding a combination of the flagellates Isochrysis and Dicrateria produced only about 1/5 as much growth of larvae, in ten days, as did identical concentrations of the same combination of flagellates in the experiment of March 25–April 8. This suggests that one phase of the action of the unknown factor may be to affect the ability of the larvae to utilize the food that is available.

Several authors have suspected unidentified variations in sea water of affecting their results. Loosanoff, Miller and Smith (1951) noted a lack of uniformity of results in consecutive experiments with larvae of *Venus mercenaria* and considered it possible (p. 75) "that at different times the water itself contained certain dissolved substances which, in a manner not yet understood, affected the rate of development of bivalve larvae." Wilson (1951), working in England with polychaete larvae, found a difference between sea water from two different areas and attributed the poor growth of larvae in water from one of these sources to a lack of (p. 18) "some unknown constituent, essential for healthy development" of the species of polychaetes he used. One of these unidentified variants may be that described by Collier, Ray and Magnitzky (1950) who reported a substance in sea water that can be measured photometrically with N-ethyl carbazole, the concentration of which could be correlated with the pumping rate of oysters.

Wangersky (1952) reported that the substance, measured photometrically with N-ethyl carbazole, was a mixture of dehydroascorbic acid and a rhamnoside. He concludes (p. 685) "that the vitamin is present in the sea largely in the form of dehydroascorbic acid." Although we have not yet tried dehydroascorbic acid, we have added ascorbic acid to the sea water in which the larvae were reared. This did not improve the rate of growth of oyster larvae, but merely resulted in a dense growth of bacteria which killed the larvae. Similar exploratory experiments indicate that additions of Vitamin B_{12}, iodine, Mn^{++}, Fe^{+++}, Zn^{++} or PO_4^{---}, likewise, do not improve the rate of growth of oyster larvae.

To verify that deleterious changes in the sea water in our laboratory system were not causing the poor growth and high mortalities of our June cultures, an experiment was designed to compare the laboratory sea water with sea water taken directly from Milford Harbor in enamel buckets. Parallel cultures of oyster larvae were started, two in sea water from each source. In addition a single culture of larvae of *Venus mercenaria* was started in laboratory sea water at the same time. All cultures received approximately 50,000 cells per ml./day of the "mixed Chlorella" as food.

At 14 days all the oyster larvae in sea water from both sources were dead, while the Venus larvae still appeared healthy and were growing normally. At 18 days the Venus larvae had reached setting size and a count revealed that approximately 55 per cent of the larvae that had been counted 12 days earlier while still in the straight hinge stage were still living. Thus, although growth was somewhat slower than average (Loosanoff and Davis, 1950; Loosanoff, Miller and Smith, 1951) the Venus larvae had lived and grown to setting stage, as in several previous experiments (Loosanoff, 1950), under conditions in which the oyster larvae had all died.

In other experiments water from points several miles offshore in Long Island Sound was used but again no significant difference in rate of growth of oyster larvae was noted. This experiment indicated that the "water factor" that resulted in poor larval growth was not just a local condition. We agree, therefore, with Wilson (1951), who concluded (p. 18) "it is evident that many animals find no difficulty in living and reproducing under water conditions that seem to affect some other species adversely."

We do not yet know what this "water condition" is, nor whether it is the presence of some inhibitory or toxic substance that causes poor growth, or, as Wilson (1951) believes, it is the lack of something necessary for good growth. Our experiments do indicate that one phase of its action is to affect the ability of larvae of *C. virginica* to utilize the food that is present.

The author wishes to express his gratitude to Dr. F. S. Russell of the Plymouth Laboratory of the Marine Biological Association of U. K. for sending us innocula of the six species of marine flagellates cultured by Dr. Mary Parke; to Dr. P. R. Burkholder of Yale University who isolated the nine species of marine bacteria used; and to Dr. Ralph Lewin of Yale University who isolated the *Chlorella* sp. from our mixed phytoplankton culture. The author is especially indebted to Dr. V. L. Loosanoff not only for obtaining the pure cultures of micro-organisms but also for constructive criticism throughout the experimental work and the preparation of this paper. Thanks are also due my co-workers, D. W. Calhoun, who gave valuable assistance in the statistical analysis of the data, and to W. S. Miller and C. A. Nomejko for assistance in other phases of the work.

SUMMARY

1. None of the 13 species of marine bacteria tested to date was utilized as food by oyster larvae.

2. Five species of flagellates, *Dicrateria inornata, Chromulina pleiades, Isochrysis galbana, Hemiselmis rufescens* and *Pyramimonas grossii,* were utilized as food by oyster larvae, while another, an unclassified chrysomonad, in addition to the three flagellates previously reported, was not.

3. *Chlorella* sp. was not utilized as food by young oyster larvae but was utilized during later larval stages.

4. None of the combinations of foods tried gave any evidence of providing a more balanced diet or more rapid larval growth than could be obtained by feeding equivalent quantities of a single food. The effects of all foods tested, including Chlorella, are additive.

5. When equal numbers of cells are fed, different species of flagellates induce different rates of growth of oyster larvae.

6. Species of flagellates also differ in the number of cells needed to induce the maximum rate of growth of oyster larvae.

7. The maximum concentration of food organisms that can be created in water containing oyster larvae without unfavorably affecting the larvae varies with the species.

8. With the number of food organisms equal, the rate of growth of oyster larvae had an inverse relation to the number of larvae per unit volume.

9. Variations between rates of growth of larvae in cultures receiving the same treatment in successive experiments appear to be due to some variable factor in the sea water that affects the ability of the larvae to utilize the food that is present.

LITERATURE CITED

Bruce, J. R., Margery Knight and Mary W. Parke, 1940. The rearing of oyster larvae on an algal diet. *J. Mar. Biol. Assoc. U. K.,* **24**: 337–373.

Cole, H. A., 1936. Experiments in the breeding of oysters (*Ostrea edulis*) in tanks, with special reference to the food of the larvae and spat. *Min. Agri. & Fish., Fisheries Investigations Series II,* **15**: 1–28.

Collier, A., S. Ray and W. Magnitzky, 1950. A preliminary note on naturally occurring organic substances in sea water affecting the feeding of oysters. *Science,* **111**: 151–152.

Davis, H. C., 1950a. On food requirements of larvae of *Ostrea virginica. Anat. Rec.,* **108**: 132–133.

Davis, H. C., 1950b. On interspecific hybridization in Ostrea. *Science,* **111**: 522.

Imai, T., and M. Hatanaka, 1949. On the artificial propagation of Japanese common oyster, *Ostrea gigas,* Thun. by non-colored naked flagellates. *Bull. Inst. of Agric. Res., Tohoku University,* **1**: 33–46.

Korringa, P., 1949. Difficulties encountered in tank breeding of oysters. *Special Scientific Meeting on Shellfish, International Council for the Exploration of the Sea, October 1949.*

LOOSANOFF, V. L., 1945. Precocious gonad development in oysters induced in midwinter by high temperature. *Science,* **102**: 124–125.

LOOSANOFF, V. L., 1950. Variations in Long Island Sound oyster set. *Atlantic Fisherman,* **30**: 15 and 47.

LOOSANOFF, V. L., AND H. C. DAVIS, 1950. Conditioning *V. mercenaria* for spawning in winter and breeding its larvae in the laboratory. *Biol. Bull.,* **98**: 60–65.

LOOSANOFF, V. L., AND H. C. DAVIS, 1952. Temperature requirements for maturation of gonads of northern oysters. *Biol. Bull.,* **103**: 80–96.

LOOSANOFF, V. L., AND R. R. MARAK, 1951. Culturing lamellibranch larvae. *Anat. Rec.,* **111**: 129–130.

LOOSANOFF, V. L., W. S. MILLER AND P. B. SMITH, 1951. Growth and setting of larvae of *Venus mercenaria* in relation to temperature. *J. Mar. Res.,* **10**: 59–81.

WANGERSKY, PETER J., 1952. Isolation of ascorbic acid and rhamnosides from sea water. *Science,* **115**: 685.

WILSON, D. P., 1951. A biological difference between natural sea waters. *J. Mar. Biol. Assoc. U. K.,* **30**: 1–19.

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248. UTILIZATION OF DIFFERENT FOOD ORGANISMS BY CLAM LARVAE. Harry C. Davis and Victor L. Loosanoff, U. S. Fish and Wildlife Service, Milford, Connecticut.

The rate of growth of clam larvae *(Venus mercenaria)* has been used as the criterion to evaluate different micro-organisms as larval food. Growth of larvae in a control culture receiving no supplemental food was compared with growth of larvae in cultures receiving different species of micro-organisms as supplemental food. The species used and the concentration of cells fed per cc. per day were (a) Chlamydomonas 20,000; (b) *Chlorella sp.* (pure culture) 50,000; (c) *Chromulina pleiades* 30,000; (d) *Isochrysis galbana* 30,000; and (e) *Porphyridium sp.* 50,000. At eight days the average lengths of larvae in the cultures were: control 124 μ; (a) 174 μ; (b) 165 μ; (c) 155 μ; (d) 150 μ and (e) only 122 μ. In cultures (a), (b), (c), and (d) the larvae grew to metamorphosis in ten to twelve days, thus demonstrating that *Chlamydomonas sp.*, *Chlorella sp.*, *Chromulina pleiades* and *Isochrysis galbana* were utilized as foods.

After the tenth day, feeding of *Porphyridium sp.* was discontinued, and the culture was given 50,000 cells per cc. per day of mixed phytoplankton consisting chiefly of Chlorella. Within five days the larvae grew from an average size of 129 μ to a size at which metamorphosis normally occurs (185–210 μ). However, the larvae continued to grow and many retained a powerful functional velum until they reached 260–270 μ in length even though they also possessed a well developed foot and gills. Never before in over five years of culturing clam larvae at this laboratory had one that measured more than 240 μ been seen with a functional velum. This and subsequent observations suggest that clam larvae may, under certain conditions, grow considerably larger than the normal range of 185–240 μ before metamorphosis is completed.

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AERIAL METHODS OF ASSESSING RED SALMON POPULATIONS IN WESTERN ALASKA

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VISUAL SURVEYS

In western Alaska, principally in the Bristol Bay region, aerial methods of recording quantitatively sizes of populations of red salmon (*Oncorhynchus nerka*) on spawning grounds have been highly developed. The streams are generally shallow with little overhanging foliage, and in spawning colors the fish are bright red and highly visible. These characteristics increase the efficiency of aerial surveys.

The first recorded aerial stream survey in Alaska was made by C. M. Hatton, a special employee of the U. S. Bureau of Fisheries, in the Lake Clark district of Bristol Bay in 1930. Since his late arrival in the area precluded his making a ground survey he chartered an airplane to make a visual survey of the spawning beds.

In 1931, Dennis Winn, Bristol Bay Management Agent of the Bureau of Fisheries, undertook the first extensive aerial spawning ground surveys which lacked significant success because the airplane used was available for only a brief period during which low ceilings prohibited flying at an altitude sufficient to permit good observation.

Serious use of aircraft for surveys was not continued until 1937, when Agent Fred O. Lucas used this method because of lack of funds and personnel for ground surveys. In 1938 George B. Kelez, initiating a biological research program in Bristol Bay for the Bureau of Fisheries, joined with Lucas in aerial surveys, and in ensuing years developed the methods now employed.

In the widespread spawning grounds, the only alternative to aerial surveys is coverage by parties operating from boats. Because of the distances involved and the relatively short spawning season, it would be impossible for any party to cover more than one system or part of a system. To cover all of the grounds in the Bristol Bay area, nine parties of two men each would be required, complete with boats, outboard motors, camping equipment, and supplies to last a month. And even with this large crew, several major sub-systems could not be covered because they are inaccessible by boat.

Experience has shown that ground parties cannot develop accuracy of assessment comparable to that of the observer in the airplane. On small streams the former method approaches complete accuracy. However on broad streams, on lake beaches, and on large schools in the mouths of streams, surface methods of observation cannot give more than vague impressions of numbers because of reflections, the tendency of the salmon to flee when approached, and the inability of a man to see far below the surface from the angle of view obtained.

One pilot and observer team covers all of the grounds not once but three times during the season to assure observations during the peak of spawning.

Season costs of the aerial survey are under $1,000 compared to a ground-party cost of over $10,000 for manpower alone.

In developing the methods now used, Kelez (1947) made use of ground parties counting spawners on streams on the days of aerial observations. The men on the ground, in addition to making one-by-one counts of the salmon, established stations at one-mile intervals with markers visible from the air. In this way comparison of counts was readily achieved and compensations worked out.

Guessing of numbers is not suffiiciently accurate. In the aerial method developed by Kelez, two experienced observers viewing the same grounds do not differ significantly in their estimates. Ideally, observers should have a background of experience in one-by-one ground counts of spawning fish in each area so they readily appreciate varying conditions of distribution in spawning array, ranks, or schools in terms of numbers as peculiar to each bottom or water type. The inexperienced observer invariably tends to overestimate numbers of fish.

The training of observers involves working with groups of known numbers of fish in training flights during which the trainee and pilot develop teamwork. The pilot undergoes indoctrination in approaching the fish in the correct manner, keeping the observer in visual contact with the fish, maintaining proper altitude, and keeping the airplane in correct relationship between sun angle and fish to avoid glare. Study and counting of fish in aerial still photographs, as well as scrutiny of color motion pictures of red salmon in various spawning distributions taken from the air, aid in developing accuracy in the new observer.

The survey airplane moves over the stream or beach at a constant altitude. The observer varies his procedure with the concentrations of fish. On sparsely covered grounds the fish are individually counted with a hand tally. On the majority of normal groups the observer counts ten individuals, mentally connects ten such groups into a block of 100 fish, and then divides an entire group into such blocks. When large groups are present, it is necessary to circle continuously until all fish are counted. On broad streams with heavy spawning, blocks of 1,000 fish are similarly developed. As may be expected, accuracy is inversely proportional to density of populations.

Choice of altitude is extremely important. The usual impulse of beginners is to fly too low, with the result that they cannot possibly encompass what they see quickly enough to make mental records. The correct altitude depends normally on the speed of the aircraft, with certain limitations. Altitudes of less than 500 feet do not permit the observer to see a broad enough area to accurately cover the fish. Above 900 feet difficulty is experienced in seeing some fish. The speed-altitude table below might be of general application:

Speeds in Miles Per Hour	*Altitude in Feet*
Up to 70	500
70 to 90	600
90 to 110	700
110 to 130	800
130 to 150	900

It is fruitless to attempt accuracy at speeds above 150 miles per hour. A speed of approximately 75 miles per hour at an altitude of 600 feet provides the best results. Efficiency diminishes rapidly at speeds in excess of 100 miles per hour although general qualitative impressions without reference to actual numbers can be gained at higher speeds and greater altitudes.

Conditions of light and sun angle are important. Good surveys cannot be made late in the day when the sun angle is poor and continual change is made from deep shade to sunshine. Glare is a factor that may be reduced with polaroid glasses.

Fatigue is extremely important. Both pilot and observer suffer reduced efficiency after periods of uninterrupted survey. It has been found that by breaking up the period by landing and relaxing it is possible to extend the survey to six hours, not including the return to base. However, it is inadvisable to attempt more in one day.

Choice of aircraft becomes a compromise between desirability and availability. It is difficult to obtain all the desirable survey qualities in one aircraft and still retain its usefulness for other projects. A craft of versatile use with retention of good survey features would be a four-place high-wing monoplane with good visibility downward on either side. It should be capable of safe maneuverability at speeds under 90 miles per hour and should have a good rate of climb to combat downdrafts, a low fuel consumption, and a normal range of at least five hours.

Safe maneuverability dictates carrying the lightest load possible. Survey trips are not occasions for anyone to "go along for the ride."

PHOTOGRAPHIC SURVEYS

Kelez (*loc. cit.*) dwelt on the possibilities of vertical aerial photography as a means of providing permanent records of spawning numbers in various locations. Under a project jointly developed with Kelez, the writer initiated experimental work in this procedure during the 1947 season. An F-56 Fairchild aerial camera with $8\frac{1}{4}$-inch lens was mounted in the after belly of a Norduyn Norseman aircraft on floats. The F-56 is a military-type camera, electrically wound and operated, although it can also be operated manually. Stops from $f=4$ to $f=22$ are provided and a between-lens shutter gives speeds of 1/75, 1/125 and 1/225 second. Approximately seven-inch-square pictures are made on roll film in lengths up to 125 feet.

Development of the photographic system involved two main categories of problems. First was finding film, developer, and filters that would provide the highest contrast between fish and background and make the best use of light rays transmitted by water. Secondly it was necessary to find means of obtaining pictures against the odds of low light intensity, high shutter speeds and relatively small diaphragm stops.

The craft used for photographic surveys has been the result of availability rather than choice. The Norseman was used one season, following which the camera was mounted in a twin-engined Beechcraft 18-S. It has been used in that airplane to this time. Both of these aircraft are too fast and lack maneuverability and effective communication between pilot and photographer. The most serious disadvantage is the lack of visibility ahead and down. This last feature means that many retakes are necessary because the first runs are to one side of the intended picture area. This centering difficulty necessitates higher-than-desirable altitudes.

High speeds predicate high shutter speeds, which in turn mean larger diaphragm openings and intensify the problem of obtaining enough light to give good pictures. This is particularly critical in view of the high light demand of the filters normally employed. Diaphragm openings greater than f 5 result in poor coverage to the corners of the picture.

Camera movement in relation to the ground is a continuing problem with higher speeds. At 1/225 second exposure, the fastest shutter speed available, the camera moves over the ground 5.4 inches at 70 miles per hour, 7.7 inches at 100, and 9.2 inches at 120 miles per hour during the period in which the shutter is open. With fish averaging 25 inches in length, blurring is difficult to eliminate.

The ideal photographic aircraft includes features similar to those previously cited for a visual survey airplane.

The high light demand occasioned by the peculiarities of underwater photography is alleviated by using film with an index speed of 200 increased to 1,000 through use of a special developer. Orthochromatic film would provide the utmost contrast between the red fish and the bottom; however this is not available in aerographic roll film. Infrared film is often suggested as theoretically it could produce white-appearing fish in dark water. In practice, however, it produces jet-black water with nothing visible below the surface. In printing, maximum contrast is obtained by using the hardest paper available and strong developing solutions.

Filtering is one of the principal research grounds in this problem and one in which efforts continue. The most successful filters used include a deep yellow, a dark green Wratten No. 57, and a light green Wratten No. 59 A. No single filter is usable in all situations, the selection depending mainly upon the type of bottom and water depth. Best results were obtained on most gravel and sand bottoms using a yellow filter with a factor of 2.0. On bottoms covered with vegetation or algae, the Wratten 59 A with a factor of 3.5 was most effective. In deeper water the Wratten 57 (factor of 5.0) was most receptive to the spectral rays transmitted by water. A pola-screen with a factor of 2.0 was of value in reducing reflections.

The normal altitude employed with aircraft used to date was 1,000 feet. Use of a slower airplane with good visibility would permit altitudes as low as 500 feet and would cover a ground strip about 510 feet in width. With a slow, easily directed airplane, the minimum altitude would be governed only by the width of the spawning ground and the latitude of stream meander.

Obviously to photograph all, or even a large part, of the spawning grounds would necessitate prohibitive quantities of film, time and facilities to process and interpret pictures. Instead, representative areas are chosen to provide indices to adjacent spawning grounds. Normally the mouths of streams are covered, as well as portions of easily identifiable spawning grounds above. Beach spawning areas and broad, short spawning grounds such as frequently occur at outlets of lakes or in streams connecting lakes are often covered in their entirety. In this way every major spawning ground is represented. By using a large number of index areas, an average is reached which tends to compensate for the expected sampling variations. Approximately one thousand photographs are made on the Bristol Bay spawning grounds each year.

Timing of photographic trips is highly important if pictures are to be valid indices, but fortunately peculiarities of the area and the fish favor representative coverage. For example, the grounds must be covered in close proximity to the peak of spawning, and although peak periods vary among systems, variation has been well established through years of visual surveys. The salmon arrive on various spawning grounds from one to seven weeks before spawning. Salmon are present on the grounds for another two weeks between the time when spawning commences and death of the fish. Thus a minimum period of about three weeks is available within which coverage can be assumed to be representative of the run. Photography is scheduled for the mid-point of this three-week interval.

Visual advance coverage reveals the progress of spawning. The pictures themselves show the status of spawning. Earliness is indicated by large schools of fish with few nests. Widespread spawning, few schools, and few or no spawned or dead fish indicate ideal peak timing. Absence of schools, empty nests, and large numbers of dead and partially-white spawned fish indicate late coverage.

In interpreting the pictures, a sheet of clear plastic gridded into one-tenth-

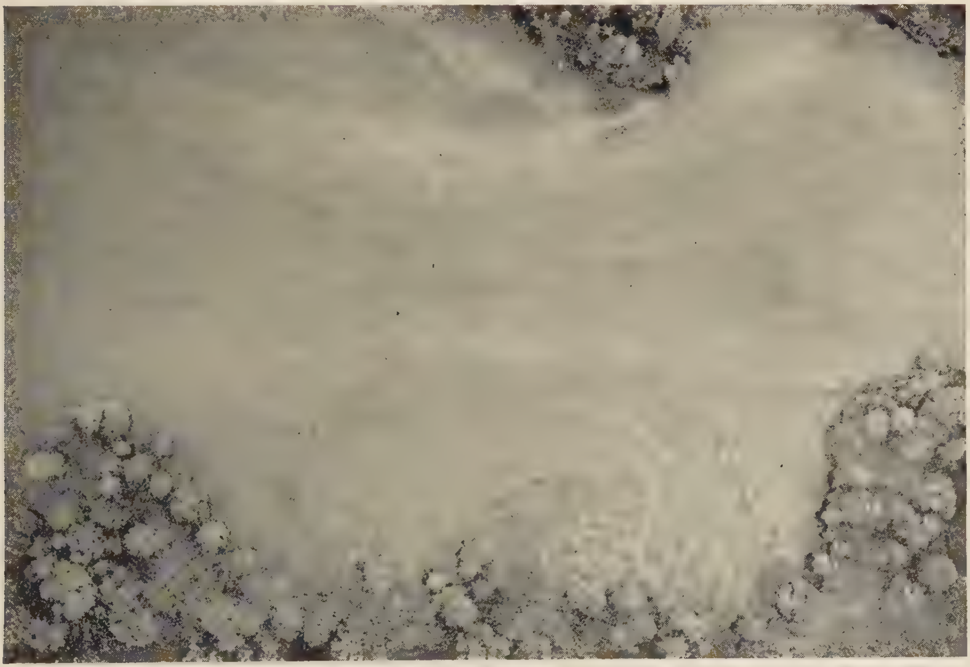

FIG. 1. A section of spawning grounds of Kejik River in the Lake Clark region of Bristol Bay. Note complete absence of salmon. Photograph made August 14, 1949.

inch squares is laid over the photograph and the fish are counted. When numbers are small, one-by-one counts are made. On large spread-out grounds, counts of representative squares are made and the average multiplied by the total squares covering fish. In the case of particularly dense schools, estimates of the average numbers in each square are made along with the actual water surface area covered by each square and the number of fish determined by visible shadings of density. Lines are drawn on the photographs connecting prominent objects serving as reference points, and the fish bounded by these lines are those counted each year.

The prints are filed by area; negatives are retained and handled in the original rolls. The 65-foot size is most easily handled. Film processing is accomplished with an automatic continuous-roll-film kit, a simple and compact apparatus utilizing three five-quart containers for solutions. Drying is done with a portable rapid film dryer developed for the military. In processing, film is wound and rewound through the solutions from one reel to another. To avoid inadequate development near the roll ends, the last five frames are left unexposed and the five-foot leader on the other end retained when processing.

Aerial photographs provide a permanent index, free of the vagaries of human memory and error, for rating visual counts. Adequate coverage is provided in large beach and stream areas or in heavy concentrations, permitting accuracy of assessment not approached by any other method.

Figures 1 and 2, taken August 14, 1949

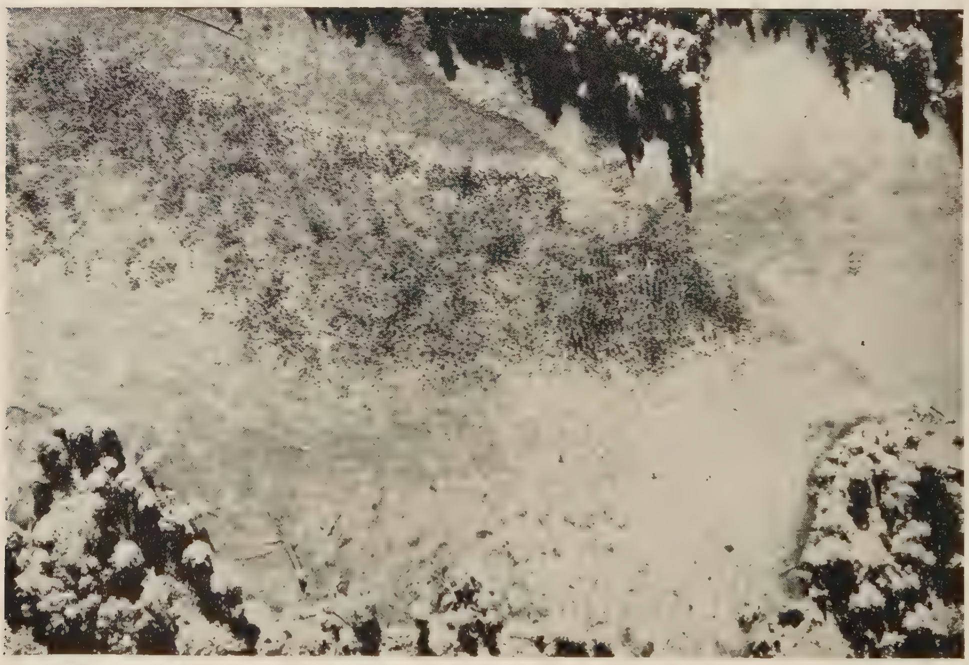

FIG. 2. Identical section of the spawning grounds of Kejik River appearing in Fig. No. 1. Only red salmon utilize these spawning grounds at this time. Photograph made August 21, 1952.

and August 21, 1952, show an identical portion of the Kejik River spawning grounds in two different years. Visual surveys found the spawning escapement to the Kejik notably poor in 1949 and very good in 1952. The seven-day difference in the dates of coverage is not considered sufficient to affect the counts. In 1952 a visual survey on August 16 found the same numbers of fish present, and in 1949 similar coverage two weeks after the photographic survey also found no fish present at this spot. This particular area is one impossible of accurate coverage by ground parties as the stream is quite broad and the fish, when present, quite concentrated. Visual aerial coverage yields good results in an area of this type but falls short of the accuracy to be obtained from pictorial records.

The photographic method of survey is relatively inexpensive. At present, cost of the aircraft charter is about $600, film $150, developer $50, and processing $200—a total of $1,000. With a small airplane used simultaneously for visual surveys, this figure would be approximately halved. This is an insignificant cost for a permanent record of spawning populations on which hinge an industry with an annual production in excess of twenty-five million dollars.

SUMMARY

1. A method of visual aerial survey of spawning red salmon on Bristol Bay grounds has been developed for assessing the populations quantitatively.

   a. Best results are obtained with good light conditions using an airplane speed of 75 miles per hour from an altitude of 600 feet. The best aircraft for the purpose is a four-place, long-range, high-performance craft which can be safely and easily maneuvered at speeds under 90 miles per hour.

   b. Fatigue lowers efficiency of survey and no more than six hours should be attempted in one day.

2. The use of vertical aerial photographs provides permanent records of indices to spawning numbers, removes much of the human error from visual counts and provides greatest accuracy when large schools are encountered.

   a. Aircraft qualities for photography parallel those needed for visual surveys but in addition include good visibility ahead and down, and low, safe, minimum speeds.

   b. Using an F 56 camera with $8\frac{1}{4}$-inch lens, altitudes range from 500 to 1,000 feet depending upon stream width and adaptability of the aircraft.

   c. Yellow, green, and polaroid filters are used in conjunction with fast panchromatic film to give greatest contrast between fish and bottom. The greatest problems arise from high light demand and camera movement.

   d. Problems in coverage at the correct time to include all spawners are alleviated by concurrent visual surveys and consistency of the species.

   e. Photographs are interpreted by counting fish in squares on a plastic grid superimposed on the print. Area of each square of the grid can be computed from the known altitude.

3. Visual and photographic methods of aerial coverage are less costly than ground counts and provide higher degrees of accuracy.

LITERATURE CITED

KELEZ, G. B. 1947. Measurement of spawning populations by means of aerial photography. Pacific Fisherman, **45**: 46–51.

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JAPANESE 1952 NORTH PACIFIC SALMON-FISHING EXPEDITION

By Francis M. Fukuhara*

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INTRODUCTION

Under the provisions of the International Convention for the High Seas Fisheries of the North Pacific Ocean (signed at Tokyo May 9, 1952, but subject to ratification by Japan, Canada, and the United States), Japan agrees to abstain from fishing for the five species of Pacific salmon east of a provisional line of demarcation starting at the edge of territorial waters north of Atka Island, following meridian 175° west longitude and the International Date Line to Bering Strait, and ending at Cape Prince of Wales, Alaska. A protocol to the Convention further

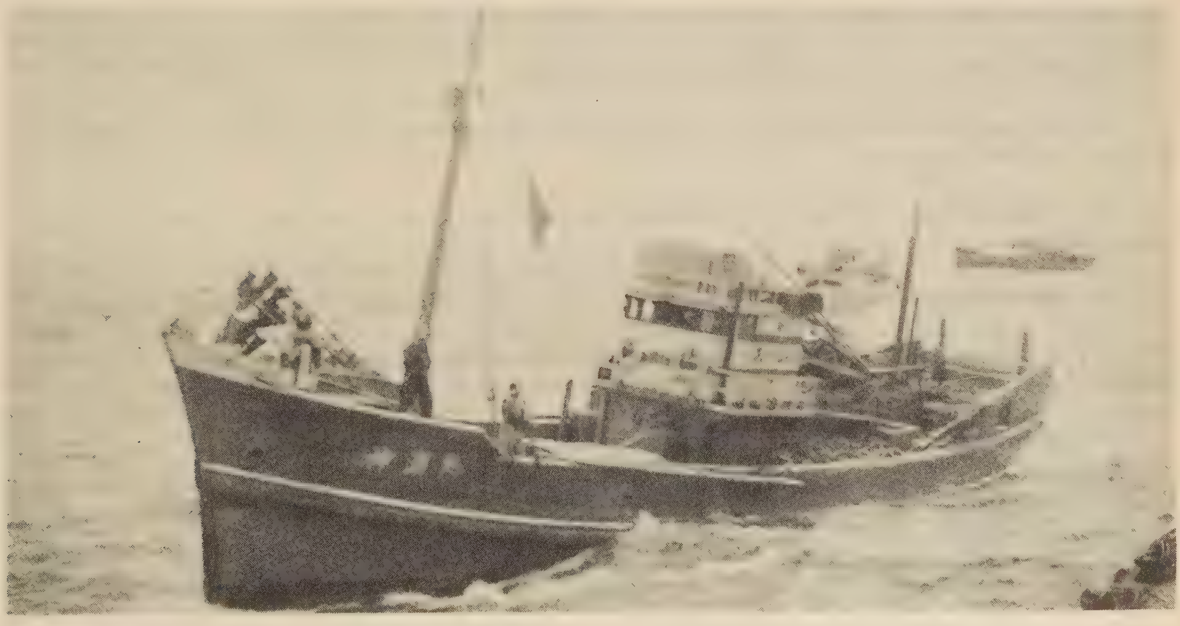

FIGURE 1 - TYPICAL CATCHER BOAT OF THE *TENYO MARU NO. 3* FLEET.

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provides for scientific investigation to determine if there is intermingling of Asian and American stocks of salmon. If areas of intermingling are found, there are to be further studies to locate a line which will best divide salmon of Asian origin from those of American origin.

An initial step in determining the distribution of the salmon in the North Pacific Ocean was made possible by an invitation from the Government of Japan for the United States Government to send a technical observer to accompany the 1952 Japanese North Pacific Salmon Expedition. This invitation was not required of Japan by any previous agreement with the United States, but was made as a gesture of good will and cooperation. In response to this invitation, the Pacific Salmon Investigations of the U. S. Fish and Wildlife Service was directed to place a biologist aboard the mothership of the Taiyo Fishing Company Ltd. fleet. It was in this capacity that I was detailed aboard the mothership Tenyo Maru No. 3, accompanying the expedition from June 1 to July 18, 1952.

Transportation from Adak, Alaska, to the Tenyo Maru No. 3 was provided by the U. S. Coast Guard Cutter Sweetbriar. Removal from the Tenyo Maru No. 3 at the end of the assignment and transportation to Adak, Alaska, was facilitated by the U. S. Coast Guard Cutter Storis. Communication to and from the Tenyo Maru No. 3 was made possible through the facilities of the Seventeenth Naval District. Data of importance to the assignment were also supplied by this organization, and travel in the Aleutian Islands was expedited by the kind attention of its various members.

The hospitality extended, as well as the cooperation and aid rendered by the Chief Inspector of the Japanese Fisheries Agency and various members of the Taiyo Fishing Company fleet is gratefully acknowledged.

In cooperation with biologists of the Japanese Fisheries Agency, who worked on their own vessels, observations were made with the following objectives:

1. Identification of fish landed aboard the mothership and recording the amounts landed.

2. Selection of random samples from representative landings of salmon. Recording the length, weight, and sex and obtaining scale samples.

3. Collection of representative specimens.

4. Interview of fishermen to determine point of origin of fish and amount of fishing effort expended.

5. Observation of fishing methods, with notes on the catches of fish other than salmon.

6. Recording of weather, sea conditions, and surface water temperatures.

7. Notation of obvious differences in appearance of salmon landed or any change in appearance as the vessel moved from one position to another.

8. Securing of all possible information on methods of capturing live fish which could be used in a tagging experiment.

SOURCES OF DATA

Salmon catches aboard the mothership were checked periodically with an official of the company. Fishermen were interviewed daily to determine the point of origin of the fish. Point-of-origin data were secured from the fleet manager's office which received this information by radio from the catcher boats daily at 0600 and 0900 hours.

Several trips were made aboard the catcher boats to observe fishing methods and to determine the distribution of the salmon in the high seas by observing their distribution in the nets. Notes on non-salmon species were made from observations of these hauls and from observations of non-salmon fish brought to the mothership with the daily trips of the catcher boats.

Morphometric measurements of salmon were made of approximately 1,800 fish during the entire journey. Although an attempt was made to select random samples from a representative day's catch, this was not always possible for all work concerning this assignment was conducted so as not to interfere with the fish-handling operations. Therefore, it was not always possible to allocate time to the measuring of specimens when catcher boats with representative catches unloaded.

Scale samples from the measured fish were taken and are being analyzed. A separate report on the age composition of the catch will be prepared. A collection of 160 salmon was frozen and returned to Seattle. The fish were collected aboard the Tenyo Maru No. 3, and when the three fleets were dispersed, specimens were collected aboard the motherships of the remaining two fleets. Meristic counts of the respective species of this sample will be made and the results reported later. Information on methods of tagging fish were obtained in conversations with the Chief Inspector of the Japanese Fisheries Agency.

All specimens measured were selected at random from the catches of single catcher boats. This greatly simplified the establishment of the exact position at which these fish were taken, but on some days it was obvious that at best the salmon selected were representative only of the catch of the particular catcher boat from which the fish were selected, and not at all representative of the entire catch of the fleet for the day. On these days the average size of the fish in the catches from various catcher boats differed noticeably. This situation occurred frequently between June 3 and June 13 while the fleet fished the waters south of Kiska Island and from June 16 to June 30 while the fleet operated in waters south of Agattu Island and westward to 170° E. meridian, and was especially noticeable in the chum salmon.

FISHING FLEETS

Three Japanese salmon-fishing fleets sailed from Hakodate, Hokkaido, Japan, on May 1, arrived at the fishing grounds on May 10, and began operations on May 11, 1952. The largest of these was the fleet of the Taiyo Fishing Co. Ltd., which consisted of the mothership Tenyo Maru No. 3 and 30 catcher boats (fig. 1). Damages resulting from rough seas reduced the number of catcher boats to 27. Three exploratory vessels left Japan five days in advance of the departure of the main fleet. The Nichiro Fishing Co. and the Nippon Marine Products Co. fleets each consisted of 1 mothership, 10 catcher boats, and 2 exploratory vessels. Catch data from the latter two fleets were secured, but precise data concerning operations and disposition of those fleets were unavailable during the voyage. Three Japanese Government Fisheries Inspection vessels patrolled the fleets, and were also engaged in tagging operations and oceanographic investigations.

THE TENYO MARU NO. 3

The Tenyo Maru No. 3 is a 330-ft. whale-rendering ship, with a net tonnage of 3,689, and powered by Diesel engines with a combined rating of 2,250 hp. Three 50-ton compressors refrigerate the sharp-freeze compartments and the holds. Sharp-freeze compartments have a capacity of 54 tons per day. The total capacity of the four refrigerated holds is 2,225.94 cubic meters.

The Tenyo Maru No. 3 was equipped with conventional navigating instruments:

1. Gyro-compass with repeaters on flying bridge, captain's bridge, and in the wireless room for use with the radio direction-finder.

2. Marine radar, which proved invaluable due to inclement weather and the nature of the fishing operation.

3. Although equipped with a loran receiver, reception was very poor in the area of operation and further complicated by almost unceasing transmission by the ship's wireless. Loran readings were, whenever possible, supplemented or confirmed by "sun-sights"--sextant readings were taken at every opportunity, for with few exceptions, the weather conditions were such that extreme alertness was required of the officers on watch to get two or even one "fix" daily.

4. A radio direction-finder was used for checking the bearings of the catcher boats, this being done only on very foggy days and on occasions when the mothership drifted extremely far out of position.

No soundings were taken during the entire voyage, the only available instrument for this purpose being a sounding line, the use of which was unfeasable due to the great depths of the waters in which the fleet operated. The sounding line was utilized occasionally in lowering a reversing thermometer attached to a Nansen water bottle to determine subsurface temperatures. Drift was calculated by checking dead-reckoning position against observed position.

FISHING AREA

The fishing area of this expedition was designated by the Japanese Government, and limited the operations of the fleets to waters bounded by lat. 50° N. and lat. 55° N. and long. 177° W. and 170° E. (fig. 2). The catch in this area fell below expectation and consequently on July 3 the Japanese Fisheries Agency enlarged the fishing area to include waters bounded by the lines intersecting at the following points: lat. 53° N. and long. 170° E.; lat. 53°30' N. and 163° E.; lat. 48° N. and 156° E.; lat. 48° N. and 170° E.; lat. 50° N. and long. 170° E. Although the greater part of the area originally authorized lay in the Bering Sea, fishing was confined to the North Pacific Ocean.

Fishing efforts were concentrated most heavily in two general areas. From May 11 to June 13 the three fleets fished the waters bounded by lat. 50°30' N. and lat. 51° N. and long. 177° E. and 178°20' E., the locus of which is 400 miles south of Kiska. From June 5 to June 14 of this period a supply ship of the Taiyo Fishing Company Ltd., serving as mothership for seven catcher boats, fished waters southeast to southwest of the Near Islands. The fleets moved westward, and from June 15 to June 26 activity was concentrated in the waters south of Agattu Island bounded by lat. 51° N. and lat. 52° N. and long. 170° E. and long. 171° E. On June 26 the fleet moved westward. With the authorization of the new fishing area, fishing was conducted west of long. 170° E. between lat. 52°15' N. and 50°20' N.

CATCH

A total salmon catch up to July 18 of 828,888 fish was reported by an official of the Tenyo Maru No. 3 fleet. However, computed by the addition of catch data transcribed from the catcher-boat journals for June 1-July 18 and added to figures of the catch from May 11-May 31 obtained from another source, the total catch amounted to 750,265 fish (table 1). A discrepancy of 78,623 fish exists between the two totals. A small part of this discrepancy is accounted for by the occasional absence of entries in the journals of the catcher boats. The catch of the exploratory vessels is also excluded from this total, for no data was obtainable from these vessels. The remaining part of the discrepancy has so far not been fully explained.

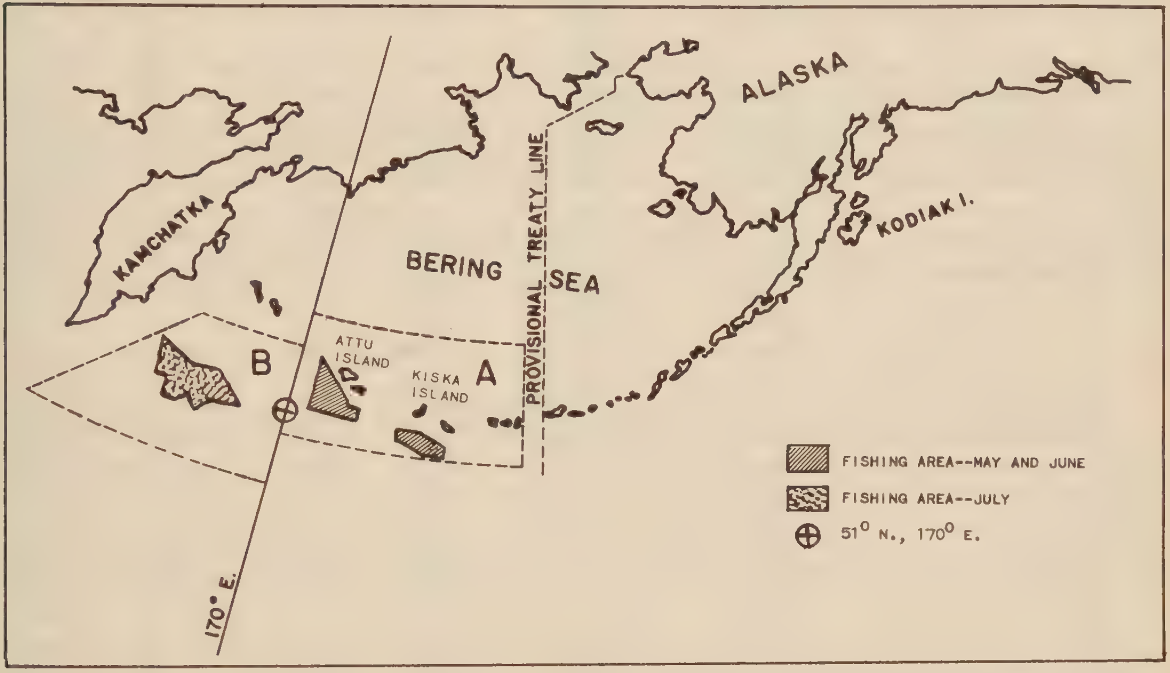

FIG. 2 - THE NORTH PACIFIC OCEAN AND BERING SEA, SHOWING JAPANESE SALMON FISHING AREAS IN 1952.

The catches of the other two fleets operating in 1952 are given in tables 2 and 3.

CATCH PER-UNIT-OF-EFFORT

Drift gill nets were used exclusively in the fishing operations. One unit of gear is called a "tan" (shackle) and has an area of .25 acres. The records of six catcher boats selected at random were used in the computation of the catch per unit of effort (table 4). On some days the operators of these catcher boats neglected to enter part of the data, and in the computations these days were excluded. In the 48 days for which data on these vessels are available, none omitted entries on more than 5 days. The number of hours fished per set is considered to be the period between the time the first "tan" entered the water, initiating the set, to the time the last "tan" was out of the water, terminating the retrieving of the gear.

Table 1 - Daily Salmon Catch, Tenyo Maru No. 3 Fleet, 1952

Date	Red	Chum	Pink	King	Silver	Total
	(Number of Fish)					
May 11-31	93,892	58,827	-	-	-	152,719
June 1	10,195	4,451	292	2	-	14,940
2	10,863	4,744	201	2	-	15,810
3	10,180	3,386	207	2	-	13,775
4	6,854	2,789	258	3	-	9,904
5	7,950	5,840	334	2	-	14,126
6	8,446	3,047	279	-	-	11,772
7	10,883	4,595	430	3	-	15,911
8	5,157	3,632	423	3	-	9,215
9	1,686	1,650	109	1	-	3,446
10	3,847	1,619	446	-	-	5,912
11	4,659	2,180	261	1	-	7,101
12	5,671	3,698	481	1	-	9,851
13	4,689	3,082	361	-	-	8,132
14	3,947	4,333	839	1	-	9,120
15	5,091	6,944	990	4	-	13,029
16	4,359	4,645	538	2	-	9,544
17	3,881	4,201	550	3	-	8,635
18	3,545	4,225	598	6	-	8,374
19	2,426	4,826	713	1	1	7,967
20	3,010	7,207	980	-	-	11,197
21	3,978	10,912	1,157	4	5	16,056
22	4,361	14,717	1,269	11	4	20,362
23	2,389	7,810	542	2	1	10,744
24	2,338	4,924	557	3	-	7,822
25	3,148	4,506	624	5	13	8,296
26	3,440	5,099	1,586	6	11	10,142
27	3,827	5,384	2,193	4	10	11,418
28	6,228	4,617	2,829	3	14	13,691
29	5,506	3,631	1,299	7	10	10,453
30	5,525	3,713	1,546	4	24	10,812
July 1	7,209	4,005	2,928	5	53	14,200
2	5,339	2,760	3,046	5	16	11,166
3	5,248	1,434	845	2	4	7,533
4	6,490	2,174	3,004	18	13	11,699
5	9,121	2,731	5,604	12	16	17,484
6	8,896	3,306	5,641	24	21	17,888
7	5,765	2,322	2,691	32	13	10,823
8	5,662	3,253	4,957	42	36	13,950
9	4,258	2,133	3,446	17	38	9,892
10	3,036	1,008	1,397	6	18	5,465
11	3,036	1,338	2,588	14	17	6,993
12	3,956	1,406	4,556	14	34	9,966
13	6,383	2,117	7,052	22	36	15,610
14	9,682	3,961	10,703	29	63	24,438
15	7,108	3,055	12,393	59	63	22,678
16	4,542	2,740	11,396	34	77	18,789
17	4,629	5,720	15,922	60	221	26,552
18	2,512	7,331	14,478	27	517	24,865
Total	260,951	199,201	135,539	508	1,349	750,265

"-" NONE.

The unit of effort used in the calculations is the tan-hour. The average number of tans per set is 134.5, obtained by dividing the total number of tans by the total number of sets (table 4). Multiplying this by the total number of hours fished (table 4) gives the total number of tan-hours, which is 456,139. Dividing the total catch for the 6 boats of 128,538 fish by the total number of tan-hours gives .2818 fish as the catch per tan-hour. The average number of hours fished per day was 14, so that the catch per tan-day was 14 times .2818, or 3.95 fish.

The catch per unit of effort probably would have increased noticeably after July 14, but due to the wear of the gear resulting from frequent fouling and the consistency with which the catches occurred on the upper half of the net, the effectiveness with which the mesh retained fish was considerably reduced. Larger runs were known to have occurred from the middle of July, for catches of 20 fish per unit of gear per night's set were made by catcher boats with new gear. In the hauling of the worn gear, fishermen reported many fish lost. The runs encountered at this time were primarily pink salmon, and due to their smaller size the failure of the worn mesh to retain fish was more pronounced.

VERTICAL AND HORIZONTAL DISTRIBUTION OF FISH IN THE CATCH

Within the limits of the depths fished by the drift nets, salmon occurred during the hours of darkness in greatest abundance near the surface, decreasing in numbers with increasing depth. Cold winds or turbulent seas appeared to force the salmon to seek greater depths, but the tendency to remain near the surface persisted. In all hauls observed, about 85 to 90 percent of the catch occurred from the float line down to 10 meters. Reports from the fishermen throughout the entire operation confirmed this finding.

A wide dispersal of salmon in the high seas was indicated by the horizontal distribution of the fish in the gear. From May 11 to June 14 little grouping of salmon was reported by the fishermen, the fish being distributed at random across the entire length of the net. Distinct grouping of the salmon later became apparent in fish taken from the waters south and southwest of Agattu Island.

Observations of two hauls in this general vicinity were made. The entire catch of one haul was taken on 75 of the 100 units of gear set. Fourteen distinct groups of salmon occurred at irregular intervals, each group composed of 10 to 15 fish spread widely over a unit of gear. These groups were not often homogeneous as to species.

A second haul at another location was made from a power launch drifting 20 units of gear. The entire catch of this haul was taken on the upper half of the net and the fish were distributed horizontally at almost regular intervals--approximately three fish to a "tan." The five pink salmon captured in this set were found to be distributed on one "tan" of gear. No noticeable grouping of red salmon was observed.

RED SALMON (Oncorhynchus nerka)

The daily catch of red salmon by the Tenyo Maru No. 3 fleet is shown in figure 3.

Red salmon predominated in the catch from the waters of the area south of Kiska Island. The bulk of these red salmon presented a slender appearance. The average length of specimens measured between June 3 and June 9 was 21.77 inches; the average weight of these same specimens being 5.34 pounds. The stomachs of all fish taken from these waters were markedly distended. Superficial analysis

Table 2 - Daily Salmon Catch, Fleet X, 1952

Date	Red	Chum	Pink	King	Silver	Total
	....	....	(Number of Fish)		....	....
May 11-31	1/	1/	1/	1/	1/	52,595
June 1	3,379	1,541	76	1	-	4,997
2	5,916	3,120	202	-	-	9,238
3	5,636	1,491	117	-	-	7,244
4	4,976	1,888	205	-	-	7,069
5	4,811	1,275	149	-	-	6,235
6	5,429	1,992	261	5	-	7,687
7	4,530	1,033	134	2	-	5,699
8	6,494	2,082	455	2	-	9,033
9	2,603	1,605	146	-	-	4,354
10	338	234	14	-	-	586
11	291	383	64	-	-	738
12	1,351	951	82	-	-	2,384
13	2,007	1,278	164	-	-	3,449
14	1,650	980	344	1	2	2,977
15	1,162	1,216	197	1	-	2,576
16	1,413	2,881	542	-	-	4,836
17	1,549	3,323	310	1	-	5,183
18	991	1,084	80	1	-	2,156
19	1,430	1,968	488	1	-	3,887
20	1,224	2,772	429	3	1	4,429
21	1,135	4,129	452	1	1	5,718
22	890	6,082	1,010	-	6	7,988
23	1,158	6,908	854	5	8	8,933
24	264	469	62	-	-	795
25	1,245	2,114	331	1	5	3,696
26	1,661	1,564	691	4	8	3,928
27	1,278	3,342	1,069	1	2	5,692
28	1,697	3,735	1,115	2	-	6,549
29	2,618	2,330	1,243	1	1	6,193
30	1,870	2,768	442	2	1	5,083
July 1	1,893	2,984	659	1	9	5,546
2	3,344	3,201	1,417	1	18	7,981
3	2,248	806	309	-	5	3,368
4	2,391	823	255	-	8	3,477
5	4,197	1,914	2,399	1	9	8,520
6	4,234	1,145	2,812	3	3	8,197
7	5,314	2,366	3,658	20	9	11,367
8	1,976	1,041	1,011	12	5	4,045
9	2,669	1,332	3,006	13	7	7,027
10	2,310	867	1,181	5	25	4,388
11	2,688	1,003	2,091	8	17	5,807
12	1,606	1,168	4,619	13	64	7,470
13	3,065	1,905	7,692	10	56	12,728
14	2,927	1,342	4,792	9	103	9,173
15	2,213	1,112	7,377	11	49	10,762
17	1,935	1,153	9,551	11	79	12,729
Total June 1-July 17	116,006	90,700	64,557	153	501	271,918
Grand Total	1/	1/	1/	1/	1/	324,513

1/ BREAKDOWN BY SPECIES NOT AVAILABLE.
"-" NONE.
NOTE: NO CATCH SHOWN FOR JULY 16.

Table 3 - Daily Salmon Catch, Fleet Y, 1952

Date	Red	Chum	Pink	King	Silver	Total
	.... (Number of Fish)					
May 11-31	1/	1/	1/	1/	1/	82,794
June 1	4,629	1,951	84	-	-	6,664
2	4,972	2,032	137	-	-	7,141
3	6,755	2,404	125	3	-	9,287
4	4,700	1,751	108	-	-	6,559
5	3,269	2,456	201	-	-	5,926
6	3,819	3,255	310	-	-	7,384
7	3,993	1,343	103	-	-	5,439
8	3,893	3,417	273	1	-	7,584
9	2,151	1,865	107	-	-	4,123
10	748	907	17	-	-	1,672
11	1,212	1,422	193	-	-	2,827
12	1,837	2,151	158	-	-	4,146
13	1,853	2,771	210	-	-	4,834
14	3,112	3,501	163	-	1	6,777
15	3,251	3,464	521	3	-	7,239
16	2,144	3,692	465	-	-	6,301
17	1,582	3,629	399	-	-	5,610
18	594	900	35	-	-	1,529
19	1,216	1,717	460	-	1	3,394
20	1,584	1,698	454	2	-	3,738
22	1,992	2,846	490	-	1	5,329
23	1,524	4,365	684	-	-	6,573
24	518	793	114	-	1	1,426
25	2,732	3,313	470	-	-	6,515
26	2,641	3,900	1,378	-	2	7,921
27	2,404	3,350	1,789	-	5	7,548
28	3,639	3,453	1,870	-	5	8,967
29	3,425	3,229	2,570	6	33	9,263
30	3,238	1,493	358	5	1	5,095
July 1	4,099	2,570	1,524	5	23	8,221
2	2,817	2,413	2,162	2	25	7,419
3	2,300	1,095	715	2	3	4,115
4	3,417	775	290	3	11	4,496
5	3,565	2,116	3,007	14	15	8,717
6	2,650	1,529	3,024	2	18	7,223
7	4,021	1,670	3,343	34	5	9,073
8	2,215	1,544	1,671	23	33	5,486
9	3,439	1,305	3,293	23	32	8,092
10	7,216	1,086	2,203	3	32	10,540
11	2,667	780	2,462	1	8	5,918
12	2,636	1,409	6,318	4	36	10,403
13	1,732	1,271	3,346	3	39	6,391
14	722	1,370	2,337	9	58	4,496
15	1,763	1,623	4,713	35	44	8,178
16	1,496	1,430	6,540	22	58	9,546
17	1,688	1,378	8,198	19	123	11,406
Total June 1-July 17 ..	127,870	98,432	69,392	224	613	296,531
Grand Total	1/	1/	1/	1/	1/	379,325

1/BREAKDOWN BY SPECIES NOT AVAILABLE.

"-" NONE.

NOTE: NO CATCH SHOWN FOR JUNE 21.

showed that the stomachs of the red salmon contained squid up to five inches in length, adult lantern fish (family Myctophidae) up to five inches in length, larval lantern fish with yolk sacs still attached, and several species of adult and larval crustaceans.

Data obtained from interviews with fishermen indicated a considerable randomness of movement of the fish in this area. Throughout the month of May the fish were frequently caught in equal numbers on both faces of the net, regardless of the direction of the set. From June 1 to June 8, randomness was still evident, the fish approaching from the N., NE., ENE., ESE., S., SW., and W. From June 9 the direction of approach of the fish was from the south to the east.

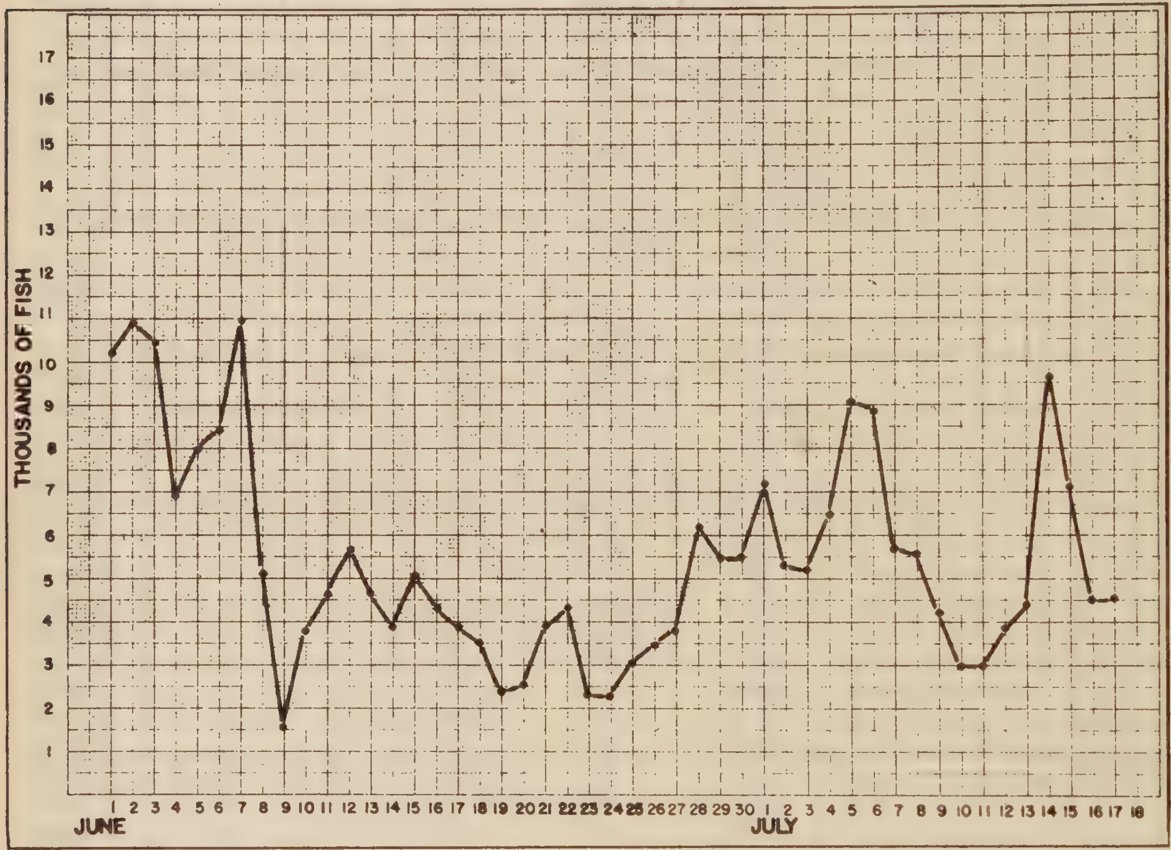

FIGURE 3 - RED SALMON CATCH OF TENYO MARU NO. 3 FLEET, JUNE 1-JULY 18, 1952 (IN NUMBERS OF FISH PER DAY).

On June 14 the composition of the catch changed, with the number of red salmon decreasing and the number of chum salmon increasing (fig. 4). Also, an abrupt difference in the body proportions of the red salmon was noticed. Red salmon caught on that day were noticeably stouter and deeper-bodied than those previously encountered. The average length between June 14 and June 20 was 22.15 inches and the mean weight 6.2 pounds. Red salmon showing greater depth through the body from dorsal to ventral surface persisted in all catches until July 5.

Red salmon taken on June 14 and 15 were feeding very lightly or not at all. Heavy feeding was indicated in all of these fish landed from June 16 to July 18. Stomach contents of these fish showed a marked decrease in squid, and lantern fish were no longer seen. Many of the stomachs of salmon taken in the fishing area south of Agattu contained juvenile cod (species unknown).

On June 28 red salmon regained predominance over the chum salmon and retained it until July 19. A decrease in the number of the stouter-bodied red salmon was noticeable with this change in catch composition. No detailed study concerning the sexual maturity of these fish was attempted, but a great variation in the extent of ovary development was observed. Ovary lengths were from 7 cm. to 12 cm. and the diameter of single eggs ranged from 1.1 mm. to 4 mm. No fully mature specimens were encountered at any time.

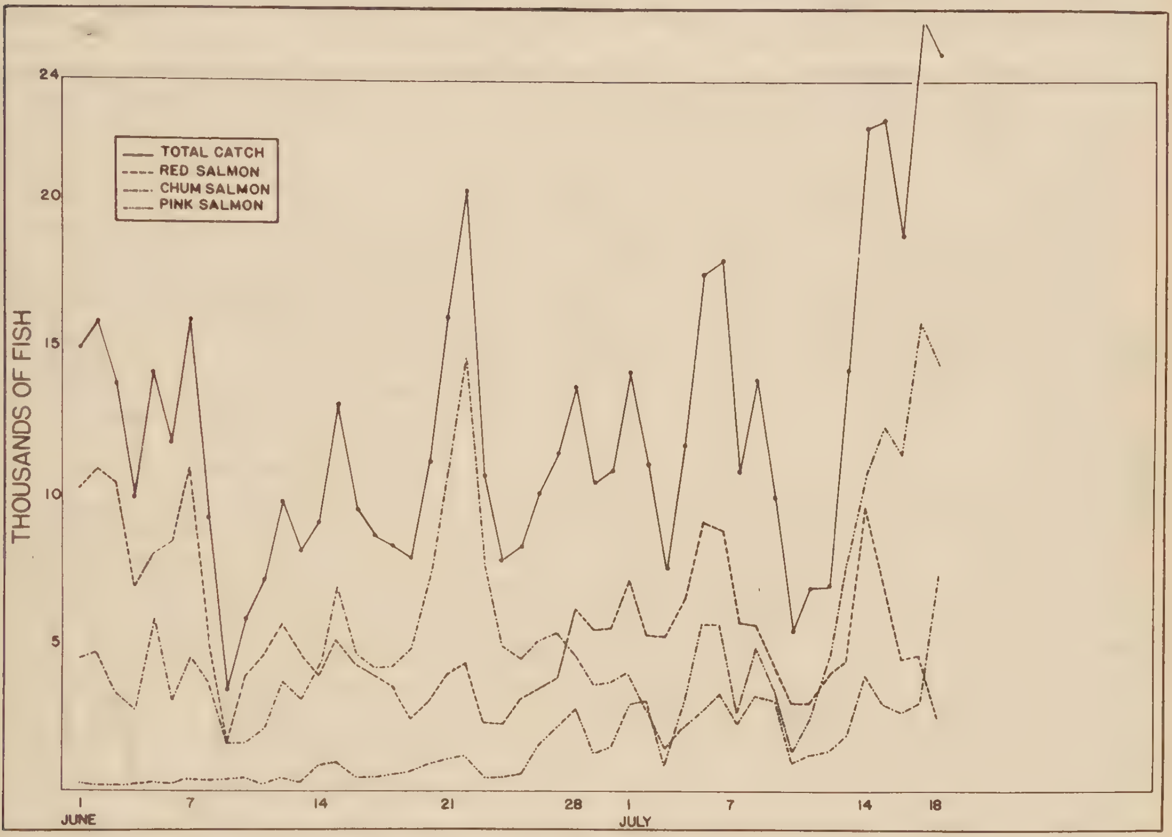

FIG. 4 - TOTAL CATCH OF TENYO MARU NO. 3 FLEET, JUNE 1-JULY 18, 1952 (IN NUMBERS OF FISH PER DAY BY SPECIES).

In the areas fished south of Kiska Island and south of Agattu Island, red salmon 12 inches long and under were occasionally taken. Although few of these were brought aboard the mothership, all specimens were males, the gonads of which were noticeably undeveloped, presenting the appearance of a string. On the evidence of the few specimens examined these fish were juvenile rather than precocious males.

Table 4 - Salmon Catch-Effort Data for Six Selected Catcher Boats

Catcher Boat	No. of Sets	Total No. of Hours Fished	No. of "Tans" of Gear Set	No. of Fish Caught
1	41	571.42	5,735	20,560
2	38	514.25	4,875	21,130
3	40	539.11	4,700	14,511
4	44	644.42	6,255	29,264
5	39	535.75	5,550	20,873
6	40	586.42	5,435	22,200
Total	242	3,391.37	32,550	128,538

CHUM SALMON (Oncorhynchus keta)

A peak in the catch of this species occurred on June 22 (fig. 5). No difference in the general appearance of the chum salmon was detected as the fleet moved from one fishing area to another. Variation in the size of the chum salmon caught was striking in the area south of Kiska Island. On June 19 the variation in size became less noticeable. Average size of the fish (average length 21.1 inches and weight 4.1 pounds) appeared to be less than that of the chum salmon taken previously in waters south of Kiska Island (average length 22.1 inches and weight 5.1 pounds). Beginning July 1 a great variation in the size of the fish in the catch became apparent, and although small chum salmon were still present, the number of salmon with a length greater than 23.6 inches increased. The average length of the chum salmon measured from July 5 to July 16 was 19.8 inches and the average weight was 5.0 pounds.

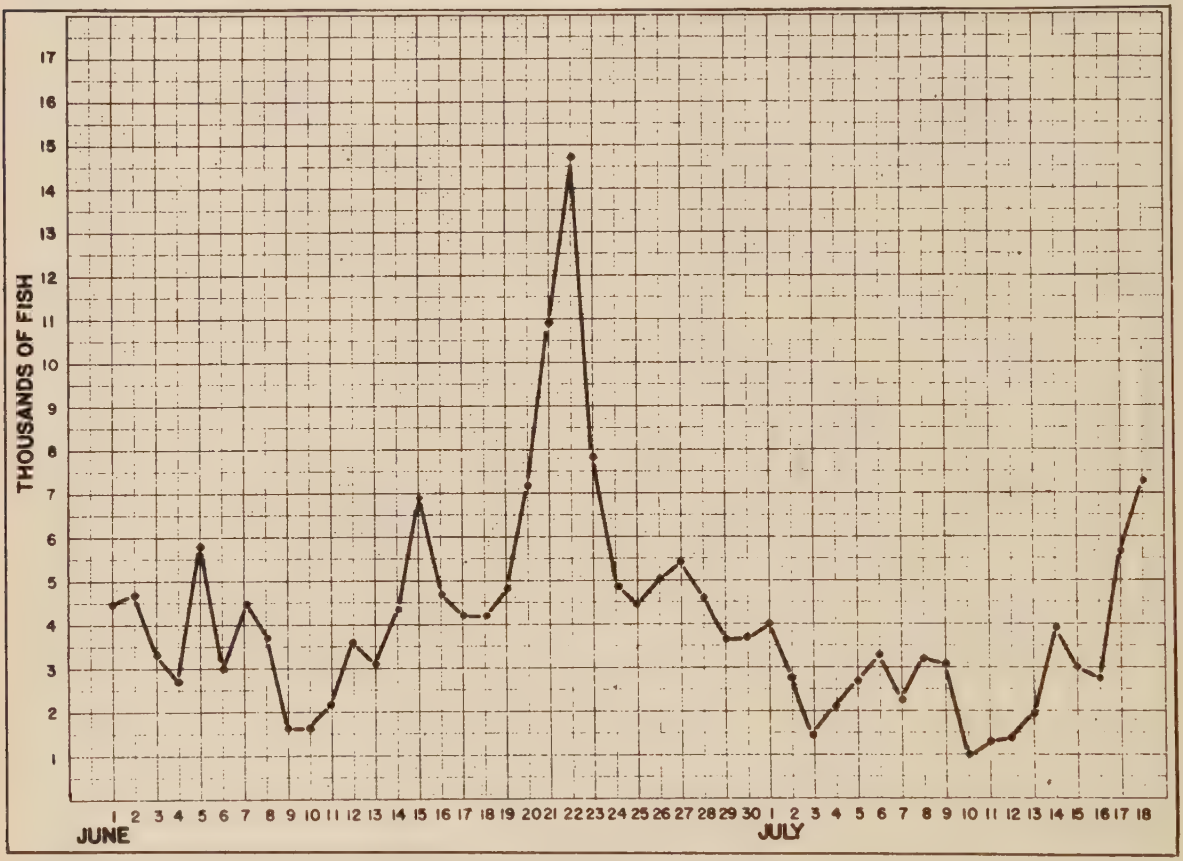

FIG. 5 - CHUM SALMON CATCH OF TENYO MARU NO. 3 FLEET, JUNE 1-JULY 18, 1952 (IN NUMBERS OF FISH PER DAY).

All stomachs examined showed evidence of heavy feeding until June 26. On superficial examination, stomachs were found to contain large amounts of mysidaceans with lantern fish and squid occurring less frequently than in the stomachs of the red salmon. Almost no food was evident in most specimens taken from June 27 to July 4.

A great variation in size of chum salmon was evident in the catches from July 1 to July 18; there was seemingly a greater proportion of large specimens (23.6 inches or longer) on days when the catch of chums was relatively large.

Invariably the stomachs of larger specimens were empty or nearly so, while those of the smaller specimens contained large amounts of food.

As with the red salmon, great variations in the degree of gonad development were evident in the chum salmon taken in waters south of Kiska between June 1 and June 14. The degree of sexual maturity of chum salmon taken from waters south of Agattu Island from June 26 to June 30 was uniform. Ovary lengths during this period measured approximately 12 cm. and the diameter of the eggs ranged from 1.5 mm. to 3 mm.

PINK SALMON (Oncorhynchus gorbuscha)

The differences detected in the external appearance of the pink salmon were due to the lateness of the season and corresponding maturity rather than specific differences related to the locality in which they were taken. Pink salmon did not appear in the catch until May 30 in the area south of Kiska Island. Their relative numbers in the catch were low and fluctuated from day to day. No secondary sexual characteristics were apparent in the fish taken south of Kiska Island between June 1 and June 14.

As the fleet moved westward to the fishing area south of Agattu Island, the catches of pink salmon increased (fig. 6). A sudden increase occurred on June 26, and the increase continued until on July 14 they predominated, making up more than half the catch on July 15 and July 18.

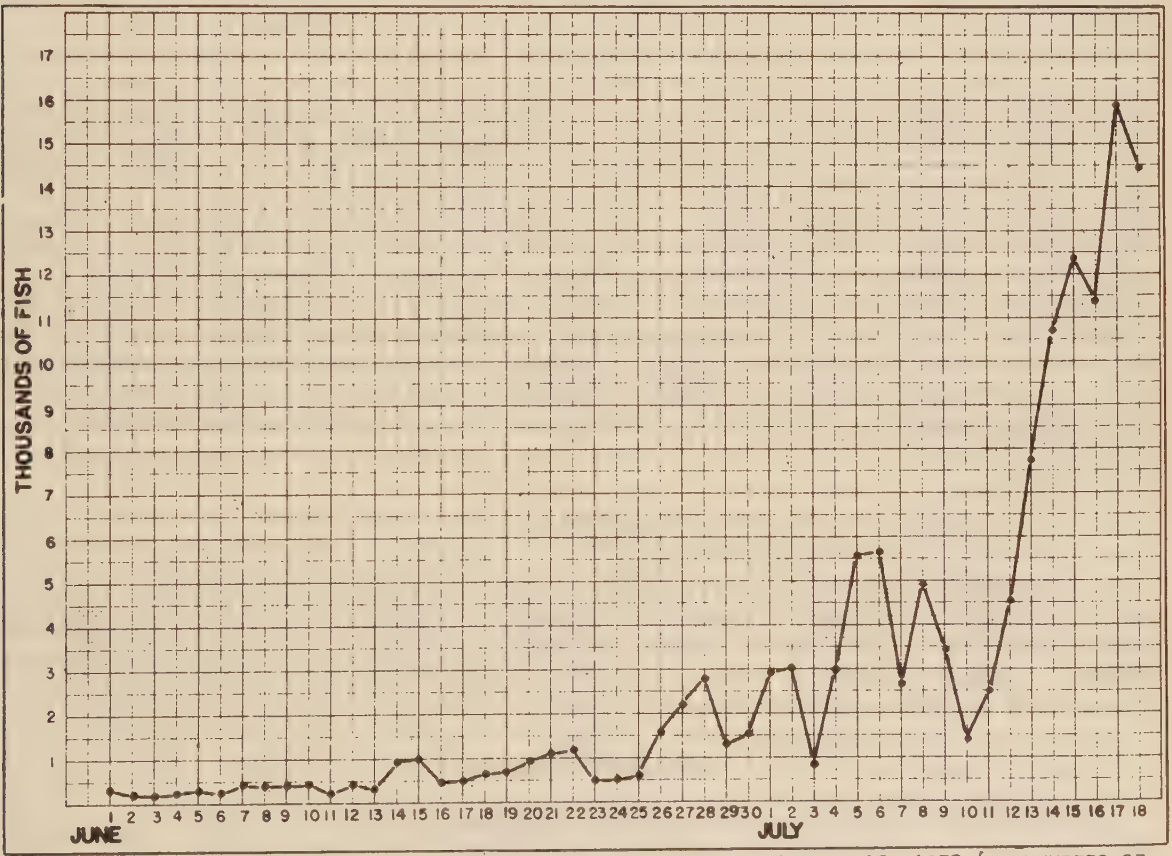

FIGURE 6 - PINK SALMON CATCH OF TENYO MARU NO. 3 FLEET, JUNE 1-JULY 18, 1952 (IN NUMBERS OF FISH PER DAY).

Pink salmon with humps began to appear on July 1, but in relatively small numbers at that time. Beginning July 4, an increase in the number of humped-back specimens occurred. The pink salmon taken after July 7 with few exceptions were humped, and scattered individuals showed crimson mottling on the pelvic and caudal fins. Feeding was extremely heavy in all specimens examined throughout the period of observation. Only 14 of the 345 specimens measured and examined were females. Gear with smaller mesh, set by the Fisheries Inspection vessels, caught a relatively larger number of females than the fishing fleet. This indicates the presence in the area of females not taken in the regular catch because of the selectivity of the gear fished. Females only 10 to 12 inches long were also taken occasionally on hand lines with hook and bait.

KING AND SILVER SALMON

King salmon (Oncorhynchus tshawytscha) from the start of the fishing operation were caught in small numbers throughout the season. Those taken in May and in the early part of June were large, weighing up to 35 pounds. The average weight of immature specimens taken subsequently was approximately 15 pounds. No measurements or other observations were made of king salmon for they occurred in relatively small numbers and the handling of them was such that they were not always recognizable when mixed with a large load of red salmon or chum salmon.

Silver salmon (O. kisutch) occurred in the catches only erratically after June 18; they were few and hardly noticeable in the landings. As in the case of the king salmon, no special observations were made of the silver salmon.

SPECIES OTHER THAN SALMON

Several species of fish other than salmon were taken but never in great quantity for an extended period. Mackerel sharks (Lamna nasus) were taken occasionally. These sharks averaged approximately 5.5 feet in length and whenever caught did extensive damage to the gear. Greenlings (Pleurogrammus sp.) were taken in small numbers in the waters south of the Aleutian Islands, but occurred frequently and in considerable numbers in the gear of catcher boats fishing in waters close to the Near Islands. One arrow-toothed halibut (Atheresthes stomias) measuring 20 inches was taken in a drift net fishing south of Kiska in waters roughly 3,000 fathoms deep. Ragfish (Acrotus willoughby) were taken occasionally in widely scattered areas. One species of cod (Theragra chalcogramma) occurred in the catches while the fleet fished west of 170° E. longitude. No accurate record could be kept of the relative abundance of these species for all but the ragfish were utilized as food by the fishermen; consequently, they rarely arrived aboard the mothership.

PARASITES

No tapeworms were found in the stomachs of the red, chum, and pink salmon until July 5. The number of specimens infested with tapeworms increased sharply within a few days. On July 16 a total of 80 red, 80 chum, and 80 pink salmon were examined. About 30 percent of the red, 50 percent of the chum, and 100 percent of the pink salmon were infested.

DAYLIGHT FISHING

Occasionally gear was set during the daylight hours. Little or no success resulted from operations until July 16, when some of the vessels were operating in the western area. Catches of seven fish per "tan" were made in this area during the daylight hours. Possibly perception of the gear by the salmon accounts for the low catches made in daylight sets. On moonlight nights fish were seen grouped on one side of the gear, swimming along its length and avoiding the net.

Similar occurrences were reported by many fishermen, some of whom made attempts to drive the fish into the nets on these occasions. Observations and reports of this nature occurred only after July 5; weather and sea conditions before this would not permit such observations.

DATA PERTINENT TO A TAGGING PROGRAM

Biologists on vessels of the Japanese Fisheries Agency conducted tagging operations. Great difficulty was encountered in capturing salmon in large enough quantities and in good enough condition to tag and release. Initially fish were captured with gill nets, but the fish were in too weak a condition to release. Attempts were made to patrol the net and remove the fish within a short time after capture, but due to rough seas and darkness this procedure was abandoned. Most fish captured for tagging by the Japanese were taken on long lines, set during the daylight hours, using salmon meat as bait. Few fish were captured by this method: only 2,000 fish were reported tagged and released up to July 18, or 29 fish per day. Records of the exact number of each species were unobtainable. The amount of effort expended in the capture of fish for tagging or the time devoted to it was not learned, although the fishery biologist in charge expressed concern over the lack of fish taken for tagging. Although the long line did not take fish in great quantity, the fish taken were said to be in much better condition for release than those taken by gill nets.

Few fish taken in the hauls of the catcher boats were in suitable condition for tagging. In one operation, 89 red salmon, 456 chum salmon, and 47 pink salmon were taken on 100 "tans" of gear. All pink salmon were dead or nearly so when landed. Chum salmon were alive, but all were exhausted and 60 seconds after landing the only signs of life seen were in an occasional movement of the operculum or quivering of the pectoral fin. Roughly 80 percent of the red salmon in this haul were in a weakened condition. But 20 percent of the red salmon of this catch were extremely lively, vigorously resisting the fishermen's grasps and flipping with considerable vitality for 90 seconds after landing.

Ten injured fish were taken in this haul. Injuries seemed to have been inflicted by sharks and sea birds, both of which were frequently caught in the nets. Three fish were brought aboard with heads completely bitten off. Injuries to the remaining seven consisted of stabs or gashes on the abdomen in the region near the caudal peduncle. The webbing seemed to cause little or no injury to the operculum or gills, but the smaller fish (all of which were snared at the anterior insertion of the dorsal fin) were invariably weak or dead when landed. In subsequent hauls observed aboard other catcher boats, all fish taken were unsuitable for tagging.

In calm seas and in good weather a power launch from the Tenyo Maru No. 3 fished waters within five miles of the mothership, setting 20 "tans" of gear. In one haul 56 fish were taken consisting of 50 red salmon, 5 pink salmon, and 1 chum salmon. The pink and chum salmon were unsuitable for tagging, for all were near death. The 50 red salmon in the catch were all lively, with more than 50 percent in good condition for tagging and release.

Catch records indicate the need for the setting of at least a mile of net to capture 60 fish. From observation it could not be determined during which hours the salmon were actually ensnared. On two occasions, while the catcher boat inspected the set, salmon could be seen striking the gear near the float line. On two other occasions no fish encountering the gear were apparent during the inspection run and it was evident from the vitality of many of the fish landed in these hauls that they became ensnared during the early morning hours. Therefore, the

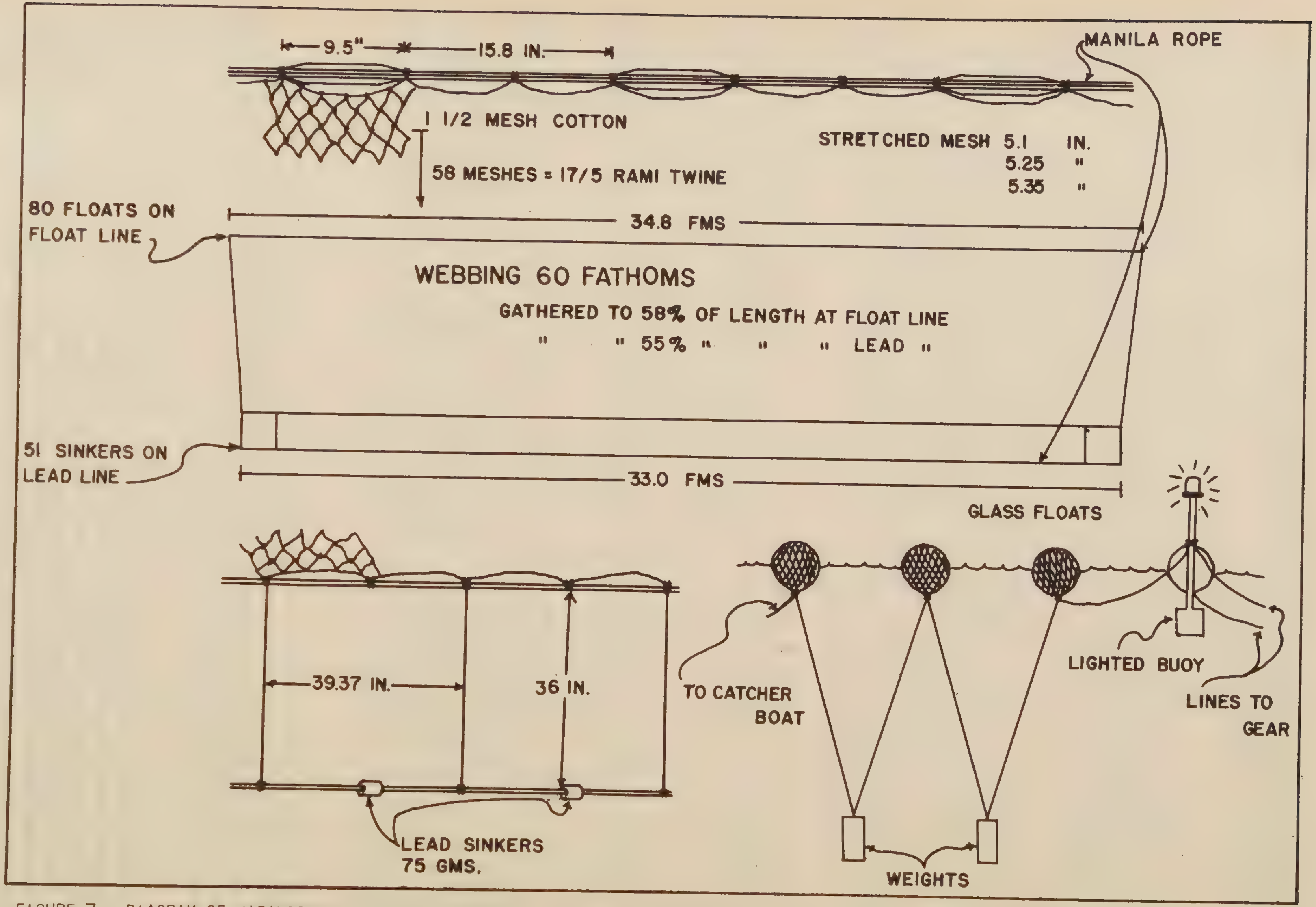
9.5"
15.8 IN.
MANILA ROPE
1 1/2 MESH COTTON
58 MESHES = 17/5 RAMI TWINE
STRETCHED MESH 5.1 IN.
5.25 "
5.35 "
80 FLOATS ON FLOAT LINE
34.8 FMS
WEBBING 60 FATHOMS
GATHERED TO 58% OF LENGTH AT FLOAT LINE
" " 55% " " " LEAD "
51 SINKERS ON LEAD LINE
33.0 FMS
GLASS FLOATS
39.37 IN.
36 IN.
TO CATCHER BOAT
LIGHTED BUOY
LINES TO GEAR
LEAD SINKERS 75 GMS.
WEIGHTS

FIGURE 7 - DIAGRAM OF JAPANESE DRIFT GILL NET USED FOR SALMON FISHING. THIS TYPE OF GEAR USED EXCLUSIVELY BY THE EXPEDITION. LOWER RIGHT- "BUMPER" APPARATUS RIGGED TO KEEP SLACK ON LINES.

possibility of good results from retrieving a mile of drift net fished for short hours without inspection of the gear is questionable. But as mentioned previously, inspection of gear can become difficult during inclement weather with heavy seas, and would be further complicated by the necessity for conducting all operations during the hours of darkness.

CONCLUSIONS

The observations made on this assignment were limited by the nature of the facilities and the necessity for conducting the biological study incidentally to a commercial fishing enterprise. It would be premature to venture a firm opinion as to the origin of stocks encountered on the basis of studies for a single season. Nevertheless, several observations indicate a mixing of stocks in the vast expanse of the area fished.

Diverse degrees of gonad development were consistently observed in red and chum salmon examined in daily landings throughout the duration of the assignment. These degrees of development seem to indicate distinct stocks or age classes of salmon, rather than deviations within a common stock.

The chum salmon taken in waters south of Kiska before June 14 were relatively small and feeding heavily. The appearance of a greater percentage of large chum salmon on days when the total chum salmon catch was relatively large suggested a migrating stock of large chum salmon passing through an area in which a stock or stocks of smaller chum salmon were feeding, for the percentage of feeding individuals on these days was noticeably less and invariably the stomachs of the larger chum salmon were found to be empty or nearly so.

Red salmon constituted the largest percentage of the landings from the waters south of Kiska Island. On June 14 as the fleet approached the waters south of Agattu Island, the catch composition changed abruptly, and chum salmon predominated in the catches.

The small amount of research into the biology of the Pacific salmon in its oceanic habitat and the limited facilities with which the duties aboard the Tenyo Maru No. 3 were conducted leaves only recourse to theories. The rate of gonad development of salmon in the oceanic habitat has not been determined. Therefore, spawning in the current year by individuals possessing immature gonads is possible but improbable.

The nature of group behavior of salmon in the high seas is unknown. The presupposition that a stock of salmon maintains its identity as a group throughout the entire duration of oceanic migration might well be erroneous, for the apparently great dispersal of the salmon as evidenced by their distribution on the gear gives no marked indication of schooling. It is possible that the indication of dispersal of salmon in the high seas from observation of the pattern of the catch on the gear may be misleading, for the disturbance created by fish snared in the gear alters the distribution of the other fish.

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The Taxonomic Status and Nomenclature of Some Atlantic and Pacific Populations of Yellowfin and Bluefin Tunas

Isaac Ginsburg

THE chief object of this paper is to analyze certain taxonomic data that have been previously published by authors regarding some populations of the yellowfin and bluefin tunas, to see what reasonable taxonomic conclusions can be drawn therefrom. Included also are some original data which have been determined on the western Atlantic bluefin tuna.

In taxonomic papers on the family Scombridae, used in a broad sense, the geographic distribution of many species is often stated to be "cosmopolitan." (For recent brief resumés of the species of this family, see Fraser-Brunner, 1950, and Rivas, 1951.) However, it should be remembered that such statements, in general, represent the subjective opinion of the author, unsupported by adequate data. This supposition is probably based on the impression that these fishes, being powerful swimmers, roam the seven seas at will. However, in at least one instance where a detailed study of comparable data has been made, namely, the comparison of the populations of bluefin tunas from the American Atlantic and Pacific coasts by Godsil and Holmberg (1950), the cosmopolitan distribution of a single species of bluefin tuna is disproved, as discussed below. It is altogether within the realm of likelihood that other so-called cosmopolitan species will prove to be composites of more than one species, on an objective study of adequate data. Some evidence is here presented which indicates that the two bluefin tuna populations on the opposite Atlantic coasts apparently belong to two distinct species. Also, evidence gleaned from the literature, although inadequate, seems to indicate that the yellowfin tuna populations should also be assigned to more than one species, or at least a number of subspecies should be recognized.

This paper of course is not a definitive finished treatment of the tunas and it is not meant to be taken as such, since extant data are meager and inadequate to solve the various taxonomic problems involved. It is rather meant to present a certain viewpoint to be taken into consideration in future attempts to solve the problem. In the absence of adequate data we must lean heavily on the known facts of the geographic distribution of fishes in general to draw plausible conclusions. Based on these two factors, our scant knowledge of the taxonomic characters of these fishes taken in conjunction with what we know of zoogeography of fishes in general, the tentative conclusions here arrived at seem to be justified. As the main reliance here is based on zoogeographic rather than morphologic considerations, and because of the necessarily tentative nature of this paper, all Latin names used are binomial, although in some instances the inadequate data would rather indicate that trinomials should more properly be used.

Thunnus thynnus (Linnaeus)

Eastern Atlantic Bluefin Tuna

Scomber thynnus Linnaeus, Syst. Nat., ed. 10 (1): 297, 1758 (inter Tropicos, in Pelago).

This species apparently diverges from the western Atlantic bluefin tuna in a number of characters as discussed under that species. Since Linnaeus did not give a definite locality for his species and his account might apply to more than one species, the name *thynnus* is here formally restricted to the eastern Atlantic population of the bluefin tuna.

Thunnus secundodorsalis (Storer)

Western Atlantic Bluefin Tuna

Thynnus secundo-dorsalis Storer, History of the Fishes of Massachusetts, 1867: 65, pl. 12, fig. 4 (Provincetown, Mass.).

The following specimens of this species were examined in the U. S. National Museum: Woods Hole, Mass. (No. 37928, 625 mm. to tip of tail). Off Cape May, N. J. (93734–5 and 93738–42, 7 specimens 675–775 mm., one partly dissected). Fulton Market, New York City (16509 and 76318, two specimens, skin and head).

The frequency distribution of the number of pectoral rays in these 10 specimens is as follows: 33 (in 1), 34 (3), 35 (3), 36 (1), 37 (1), 38 (1). For the eastern Atlantic bluefin, Heldt (1931) gave the number of pectoral rays as 30 or 31, and Chabanaud (1930: 149) gave the number of rays as 31 or 32. Frade (1931c: 143) counted the number of pectoral rays in 107 specimens with the following results: 32 (in 27), 33 (63), 34 (17). The combined observations by these three workers on the eastern Atlantic population as compared with the above frequency distribution of the western Atlantic bluefin tuna, indicate that the two populations diverge considerably in the number of pectoral rays, but they also overlap and the precise degree of divergence remains to be determined.

Godsil and Holmberg (1950) published counts of the fin rays and gillrakers of 6 specimens of the Western Atlantic bluefin tuna, and I determined the same counts on 5 other specimens. The combined counts of these 11 specimens are now compared with similar counts made by Frade (1931c) for the eastern Atlantic population, on the coast of southern Portugal.

First dorsal.—Western Atlantic: 13 (in 5), 14 (6). Eastern Atlantic, 104 specimens: 10 (1%), 12 (6%), 13 (60%), 14 (33%).

Second dorsal.—Western Atlantic: attached rays 14 (in 5), 15 (5), 16 (1): finlets 8 (6), 9 (5); combined number of rays and finlets 23 (10), 24 (1). Eastern Atlantic: attached rays 12 (in 3), 13 (41), 14 (67); finlets 8 (1), 9 (72), 10 (38); combined number of rays and finlets 21 (1), 22 (12), 23 (94), 24 (4).

Anal.—Western Atlantic: attached rays 13 (1), 14 (9), 15 (1); finlets 8 (11); combined number of attached rays and finlets 21 (1), 22 (9), 23 (1). Eastern Atlantic: attached rays 12 (4), 13 (79), 14 (19); finlets 7 (1), 8 (41), 9 (60); combined number of rays and finlets 19 (1), 21 (29), 22 (68), 23 (4).

Comparing the above data, the first dorsal averages fewer spines in the eastern Atlantic population, but the degree of divergence is not pronounced. A seemingly higher degree of divergence is shown by the second dorsal and anal counts. In the eastern Atlantic population, the rays average lower and the finlets higher, the divergence in the number of anal rays, judged by the data compared, is of subspecies magnitude. However, the indicated differences in the number of second dorsal and anal rays and finlets might be caused by the method of counting, rather than representing real differences. It is sometimes difficult to decide whether the last partly detached dorsal and anal ray is to be included in the count of the rays or that of the finlets. Frade might have tended to include that ray more often with the finlets, while in the counts of the American specimens it might have been included more often with the rays. When the rays and finlets are included in one count, the differences between the two populations largely disappear.

My studies of the western Atlantic scombrids leads me to consider the further probability that the preceding differences are affected by growth. That is, with growth the last dorsal and anal ray which is partly detached apparently becomes altogether separated from the rest of the fin and turns into a finlet, although the tempo of this change seems to be very slow. As a result large specimens will average fewer rays to some extent and a greater number of finlets. The differences noted above therefore, might be due to the greater average size of Frade's specimens.

The gillrakers of the American specimens vary 12–15 + 25–28, the total count being 39 (in 5), 40 (4), 41 (2). In 147 Portuguese specimens, Frade (1931c: 143) gave the gillraker count as 13 + 24 in 19 specimens and 13 + 26 in 128. His distribution is obviously in error. According to that all 147 specimens had 13 gillrakers on the upper limb and all had either 24 or 26 gillrakers on the lower limb. Those who have had any experience in the determination of intrapopulation variability in fishes in general and scombrids in particular, will know at once that such a distribution is impossible to obtain on an accurate determination, because it just does not occur in nature. Consequently, the gillraker count which, in general, is of much importance in distinguishing scombrid species, still remains to be properly compared as between the two populations concerned. Frade's faulty data perhaps indicate that the eastern Atlantic bluefin averages fewer gillrakers.

Ratios from certain measurements of 8 of the specimens listed above from Woods Hole and Cape May, 574–694 mm. in fork length (distance from end of snout to end of middle caudal rays), are: depth 3.53–4.00, average

8; head 3.19–3.34, average 3.26; pectoral 8–5.32, average 4.97, in that length (all asurements taken according to the diagram olished by Frade (1931a) for the purpose of nparison). In 6 larger specimens, 1257–14 mm., from the western Atlantic measured Godsil and Holmberg (1950: 7), ratios are: oth 3.51–3.96, head 3.40–3.52 and pectoral 1–5.08. The body depth and pectoral length these 6 specimens are nearly the same as in previous 8 specimens, while the head is oportionally somewhat shorter, which is to expected because of their larger size. For 0 specimens (1070–2630 mm.) from the stern Atlantic, Frade (1931a: 119) found the oth 3.85–4.65, average 4.25; head 3.40–0, average 3.64; and pectoral 4.85–6.25, erage 5.45. The western Atlantic population en has a deeper body and to a lesser extent a ger head and pectoral. The above figures not strictly comparable as Frade's speci- ens averaged larger than those from the stern Atlantic, while in tunas the measure- ents of the depth, head and pectoral decrease oportionally in length with increase in size. hese growth changes are discussed at some gth by Frade, 1931b, and Heldt, 1927.) owever, the differences between the western d eastern Atlantic specimens shown above, ecially the difference in the depth, are too onounced to be wholly accounted for by e.

Measurements given by Heldt (1927) of the editerranean bluefin do not differ much from ose given by Frade (1931a and 1931b) sed on specimens from southern Portugal.

To sum up, the western Atlantic bluefin tuna verges considerably from that of the eastern lantic in averaging fewer pectoral rays and a eper body. To a lesser extent the head and ctoral also appear to average longer. Possibly gillrakers are more numerous on the erage. In view of these differences and con- ering that the two populations inhabit ferent faunal regions, it seems apparent that ey should be treated nomenclatorially as tinct. Pending a precise determination of degree of divergence between them they here designated by the use of binomials. any future comparison of the differences tween the two populations it is of course portant to use the same methods of study throughout, and measurements and counts must be made with care. It is doubtful whether the data cited above and made by different investigators are rigorously comparable.

Thunnus saliens Jordan and Evermann

American Pacific Bluefin Tuna

Thunnus saliens Jordan and Evermann, 1926: 10, pl. 1 ("Pacific coast of America north to Oregon;" type, a photograph from a specimen taken off Catalina Island, Calif.).

Godsil and Holmberg (1950) showed that the American Pacific bluefin tuna differs specifically from the western Atlantic bluefin. They diverge in the number of gillrakers (p. 11), in the length of the head and preanal distance and other measurements (p. 7), and in some internal characters (p. 39). In general, the degree of divergence between them is evidently of species magnitude, and they should be treated as distinct species, notwithstanding their treatment hitherto as belonging to the same species by most authors.

Although Jordan and Evermann's paper (1926) on the species of tunas is unsatisfactory in that it is based largely on photographs and very little or none of the critical data are included, nevertheless their name *saliens* is the only one that has been proposed for the bluefin tuna from the American Pacific coast. According to the International Rules this name is valid.

Thunnus albacares (Bonnaterre)

Eastern Atlantic Yellowfin Tuna

[*Albacores*, or *Thynni*] Sloane, A voyage to the islands Madera, Barbados, Niever, S. Christophers and Jamaica . . . 1707, vol. 1, p. 11, Tab. 1, fig. 1 (description and figure apparently based on specimen from Madeira; see below).

Scomber albacares Bonnaterre, Tableau encyclopédique et méthodique des trois règnes de la nature . . . Ichthyologie, 1788: 160 (description a translation of Sloane, abbreviated and rearranged; Jamaica only locality given, apparently a lapsus, see discussion below).

Scomber sloanei Cuvier and Valenciennes, Hist. Nat. Poissons, 1831, 8: 148 (based on Sloane's account).

Thynnus albacora Lowe, Proc. Zool. Soc. London, 1839, 7: 77 (Madeira).

Neothunnus argentivittatus Beebe and Tee-Van (in part, see below), 1936: 184 (Sloane's figure republished; eastern and western Atlantic yellowfins treated as one species).

Neothunnus albacora Schaefer and Walford, 1950: 425–43 (yellowfin tunas from Angola and Pacific coast of Costa Rica compared; use of name *argentivittatus* restricted).

The species of yellowfin tunas belonging to the subgenus *Neothunnus* evidently differ specifically in the relative length of the dorsal and anal lobes, at least on the average and in the large specimens. In practice this character is difficult to apply because it changes much with growth and specimens of approximately similar size must be compared. Nevertheless, it seems to be of some value in separating the species. The tunas are not unique in this respect. A similar situation exists in the pompanos, *Trachinotus*, for instance, as discussed below.

A number of authors have noted that in the yellowfin tunas the second dorsal and anal lobes vary markedly in length. These observations have been summarized by Beebe and Tee-Van (1936: 187–88) who quoted from Cunningham (1910: 106), Kishinouye (1923: 446), Frade (1931a: 126), Herre (1936: 106) and Walford (1937: 7). From the remarks made by Kishinouye and by Frade one might infer that two forms or varieties of the yellowfin tuna exist in Japan and the eastern Atlantic, respectively, one with long lobes, the other short-lobed. However, no evidence is produced by these authors to show bimodality in the frequency distribution of these measurements at a given size range, and it is quite likely that their two varieties merely refer to specimens at the two extremes of a regular frequency distribution. Cunningham concludes that it is an age character, the lobes becoming elongated with growth. According to Walford's observations the lobes are "of all lengths, intergrading to such a degree that it was impossible to separate them into two distinct groups." This author also adds significantly that: "In general, the largest, consequently the oldest fish had the longest fins." According to Herre there is "every graduation in the length of the dorsal and anal lobes" and he does not mention any possible relation between the relative length of the lobes and the size of the fish.

The tentative conclusion that may be drawn from a consideration of the sum total of the above observations, is that the lobes become elongated with growth, but at any given size there is a wide range of variation in their length. However, these observations evidently represent merely the general subjective impressions of their respective authors and can hardly form a basis for definite conclusions.

In a brief summary of the family Scombridae, Fraser-Brunner (1950: 144) has the following to say in regard to the question of the length of the lobes in yellowfin tunas: "In some quarters it is still insisted that *T. allisoni* is a distinct Atlantic form characterized by long dorsal and anal fins; such elongation is to be found, however, in all localities where the species reaches full size (note for example the *Neothunnus itosibi* of Jordan and Evermann from Hawaii)." However, no evidence is presented in support of these generalizations regarding the morphology of these fishes. That degrees of differences do exist between the populations of the yellowfin tunas in the length of the dorsal and anal lobes is shown by the evidence discussed hereafter.

An objective study of the variability and growth changes in the length of the dorsal and anal lobes of two populations of yellowfin tunas has been published by Schaefer and Walford (1950). Their study is based on measurements of 60 specimens, 491–1626 mm. long, from Angola made by L. A. Walford, as compared with measurements of 46 specimens, 542–1571 mm. long, from the Pacific coast of Costa Rica made by J. C. Marr and by M. B. Schaefer (see Schaefer, 1948). A similar study was published by Schaefer (1952) comparing measurements of 203 specimens of the yellowfin population from Hawaii with the above specimens from Costa Rica.

The data forming the basis of the two papers cited, that are used by their authors for the purpose of plotting regression lines to show the divergence between the populations, are here reworked and put in a form comparable to that usually employed in taxonomic treatises, and especially one by which the degree of divergence between the populations is more plainly indicated.

Parenthetically it might be added that straight regression lines to show growth changes in the various measurements of fishes should be used with caution. While the study of growth changes in measurements may be said to be still in its infancy, it appears very probable that in most instances such changes are rather curvilinear. The following instances may be cited. Data determined for growth nges in the body depth of *Trachinotus olinus* (Linnaeus) (Ginsburg 1952b: 81) w that the graph representing such changes l form a sharply curved line. Similar data ed on a moderate number of specimens erring to species of *Paralichthys* (Ginsburg 2a: 279–81) suggest that the graph representing the growth change in relative depth te likely will follow a sinuous course during life cycle of most species. In *Trachinotus atus* (Linnaeus) (Ginsburg 1952b: 72–, the determined data indicate that the phs representing growth changes in body th and the length of the dorsal and anal es during the life of the fish will form spicuously curved lines.

Vhen the data discussed above are divided size groups (Tables I–II), the number of ividuals, in some size groups especially, is her small. Moreover, for comparative pures it was necessary to limit the size groups such manner as to indicate best the diverice between the three populations by the ilable data, which is not altogether the way grouping would have been done if the three s of data were considered independently to ermine growth changes only. Nevertheless, spite of these difficulties, the frame of the a in the tables, at least its skeletal form, ds to the following conclusions: (1) The es increase markedly in length with growth, the rate of increase differs with the popuon. (2) At every restricted size range the gth apparently forms a regular frequency tribution as is usually found in variable data hin a given natural population, without wing a definite bimodality. The irregularities the distributions are readily ascribable to dequate sampling. (3) The spread of the tribution, in the large size groups especially, vide. This latter phenomenon is not peculiar hese tunas. It is often found in other species ich possess characters that change markedly h growth. The larger size groups especially apt to include individuals that are markedly her much retarded or much advanced in deopment with respect to the character that lergoes conspicuous changes with growth. The populations distinctly differ on the rage in the length of the lobes, except in the allest size groups.

Vhile the smaller specimens agree, or nearly agree, in the relative length of the lobes, it is legitimate to use the difference in the length of the larger specimens in determining the degree of divergence between the populations, as this is evidently an instance in which a species difference does not develop until the adult size is attained. A markedly parallel case is that of *Trachinotus falcatus* as compared with *T. glaucus* (Ginsburg, 1952: 73–74). In the latter two species the relative length of the dorsal and anal lobes is short, and about the same, in the small specimens of both species. With growth, the lobes lengthen markedly, but the rate of increase in length differs with the species and in the large specimens the difference in length becomes a good character in distinguishing the two species.

The differences in the length of the lobes between this population and the other three yellowfin populations here considered are discussed under the accounts of the latter.

Two specimens of the Angola population (here denominated *albacares* and so designated in the tables, for reasons discussed below) fall considerably out of line as compared with the bulk of the specimens (Tables I–II). One specimen in the 751–844 mm. group had the dorsal lobe 24. This specimen very likely is a precocious individual that developed one lobe to a length that is ordinarily attained by larger fish. The other unusual variant, 1468 mm., has the dorsal and anal lobes 36 and 39, respectively, whereas the highest corresponding measurements in all other specimens are 29 and 32. However, the norm of the species is not changed by this one unusual variant out of a sample of 60 specimens. Similar variants occur also in the composite sample from Hawaii.

Beebe and Tee-Van (1936) treated the eastern and western Atlantic yellowfin tunas under one heading and used Cuvier and Valenciennes' name *argentivittatus* for their composite species. However, that name is not now available for an Atlantic yellowfin tuna. Schaefer and Walford (1950: 441), after corresponding with Dr. Léon Bertin regarding the types of *argentivittatus*, formally designated a specimen bearing Paris Museum number A5816, from the coast of Malabar, Indian Ocean, as the lectotype. This action once more throws open the question of the proper scientific names to be applied to the Atlantic yellowfin tunas, that is, assuming that the Atlantic populations are specifically distinct from those of the Pacific and Indian oceans.

In discussing the nomenclature of their Atlantic species, Beebe and Tee-Van concluded that the name *Scomber albacares* Bonnaterre, which was based on a description and figure previously published by Sloane, is not applicable to a yellowfin tuna with certainty because the figure shows a short pectoral. However, Sloane's figure also shows long dorsal and anal lobes, such as apply to the yellowfin tunas only of all the known Atlantic species. After seeing Sloane's published figure, it can hardly be questioned that his specimen actually had notably long lobes. As no species is known that has long dorsal and anal lobes in combination with a short pectoral, it is more than probable that Sloane's figure was drawn from a yellowfin tuna. A damaged fin would be a very plausible explanation to account for the short pectoral as figured. As far as many of the names proposed by early writers are identifiable at all, Bonnaterre's name *albacares* evidently should be used for some species of yellowfin tuna. Taking into consideration what we know now about the structure and geographic distribution of tuna populations, *albacares* is identifiable with greater assurance than many another species established by the early authors.

In order to determine the particular species of yellowfin tuna to which that name is to be applied, it is necessary to determine the type locality of *albacares*. Sloane in his original account, after describing the species, stated as follows:

> "It is frequently taken by Sailers with Fisgigs or White Cloath, made like Flying-Fish, and put to a Hook and Line for a Bait; The Flesh is coloured, and Tasts as the *Tunny* of the *Mediterranean*, from whence I am apt to believe it the same fish. It is to be found not only about *Spain*, and in the way to the *West-Indies*; but in the South-Seas about *Guayaquil*, and between *Japan* and *New-Spain* every where."

Sloane then was of the opinion that his fish is world-wide in its distribution. Furthermore, he did not specifically give the locality of the specimen that he described and figured. However, judged by his account in relation to the context of the book—the species is treated in a section devoted entirely to Madeira—it becomes evident, at least by implication, that the specimen described and figured came from Madeira. The other localities that Sloane mentioned, as cited above, apparently are based on a compilation from the literature, citations to which he included in his account.

Bonnaterre, who formally established the name *albacares*, gave Jamaica as the only locality in his description of the species. However, Bonnaterre's account is not more than a translation of Sloane's description in abbreviated form; and his reference of the species to Jamaica is an evident lapsus that is readily explicable by the fact that the running title in Sloane's book is "*A Voyage to* Jamaica."

On the basis of the evidence then, it seems best to conclude that the type locality of *albacares* is Madeira, a conclusion already reached by Beebe and Tee-Van (1936: 186). Nevertheless, from one point of view Sloane's account, and the name *albacares* on which it was based, might be considered as referring to a composite species, since he ascribed a worldwide distribution to his species. Therefore, it is best to restrict formally the name *albacares* to the yellowfin tuna from Madeira, and it is so restricted herewith.

Thunnus subulatus (Poey)

Western Atlantic Yellowfin Tuna

Orcynus subulatus Poey, 1875, Enumeratio Piscium Cubensium, p. 71 (Cuba).

Thunnus allisoni Mowbray, 1920, Copeia (78): 9, photo. (Biscayne Bay, Fla.).

Neothunnus argentivittatus Beebe and Tee-Van (not Cuvier and Valenciennes, as restricted by Schaefer and Walford, 1950, and in part; see above), 1936: 184, pls. 3–7, figs. 5–13 (Bermuda; St. Lucia, B. W. I.; description; discussion of nomenclature and synonymy; eastern and western Atlantic yellowfins treated as one species).

Beebe and Tee-Van (1936: 189) measured the percentage length of the second dorsal and anal lobes of 5 specimens of yellowfin tuna from the western Atlantic as follows: Standard length 555 (1), D 11, A 10; 645–690 (2), D 13, A 14; 1360–1450 (2), D 36–38, A 48. Comparing these measurements with those given in Tables I and II, those of the smaller specimens about agree with the measurements of corresponding eastern Atlantic specimens, but the two large western Atlantic specimens have the lobes notably longer, at least on the rage. The length of the dorsal lobe falls out the range of the bulk of the eastern Atlantic cimens and about agrees with that of the usual variant discussed above; while that of anal lobe is markedly greater even than that the variant. The divergence in the length of anal lobe would seem to be of species gnitude or nearly so.

The measurements determined by Beebe and e-Van and by Schaefer and Walford are mparable, as in both reports the standard gth is used as the basis of computation. at Schaefer and Walford call "total length" defined by Marr and Schaefer (1949: 242) follows: "The distance from the tip of the out (most anterior point on upper jaw), with vs closed, to the cartilaginous median part of caudal fork (seating the sliding arm of the iper firmly and thus depressing the small shy flap extending posteriorly)." Therefore, otal length" as used by these authors is the ne measurement that is generally designated andard length" by other American authors, luding Beebe and Tee-Van.

Measurements of the photograph of the type ecimen of *T. allisoni* Mowbray, about 6 t long, from the coast of Florida are as lows: "fork length" 70.1 mm., dorsal lobe mm., anal lobe 34.3 mm. On a photograph "fork length," that is, the length from the of the snout to the posterior end of the ddle caudal rays, is best measured.

In order to compare measurements based on fork length with those based on the stand- length, some correction factor is needed. scombrids, in general, the fork length is not ch greater than the standard length. I have asured 12 specimens, 8 of *T. secundodorsalis* 2 each of *T. atlanticus* and *Katsuwonus amis*, and in these the difference between fork length and the standard length varies m 3.2 to 4.1 percent of the latter. Ac- dingly, 3.5 percent in round figures would m to be a fairly adequate correction factor convert one length to the other.

According to measurements published by de (1929) of one specimen of the eastern antic yellowfin tuna (p. 236) and one cimen of *T. obesus* (p. 230), the correction or seemingly should be 9 percent. How- r, the measurement that Frade described "Longueur du corps jusqu'au pédoncule caudal," is apparently less than the standard length of American authors.

Using the above correction factor of 3.5 percent, the photograph of the type of *allisoni* shows the dorsal and anal lobes to be 43 and 51 percent, respectively, of the standard length. While measurements taken from a photograph are often not very reliable, the photograph plainly shows very long lobes and the percentages here determined evidently are near enough for practical purposes.

The three large specimens from the western Atlantic discussed above, the two specimens measured by Beebe and Tee-Van and the photograph of the type of *allisoni* differ widely from 24 large specimens from the eastern Atlantic (the coast of Angola) measured by Walford. However, four other specimens, the extreme variant discussed above and three that entered the literature, altogether two from the eastern and two from the western Atlantic, are rather intermediate. One specimen from Bermuda, 1220 mm. in total length, figured by Beebe and Tee-Van (1936, pl. 4), has the dorsal and anal lobes 22 and 24 percent, respectively, also determined by measuring the photograph and calculating on the basis of the above correction factor. These measurements fall in the distribution of the group 1166–1381 mm. in standard length from Angola (Tables I–II). A much larger specimen from Maryland, 192 pounds, figured by Nichols and LaMonte (1941: 29), has the dorsal and anal lobes 27 and 37 percent, respectively, calculated the same way as the preceding specimen. The measurement of the dorsal lobe of the Maryland specimen falls within the range of the large Angola specimens, while that of the anal lobe nearly agrees with the extreme Angola variant. In contrast with the preceding two western Atlantic specimens are the following two eastern Atlantic specimens. One, the extreme variant from Angola which has the dorsal and anal lobes 36 and 39, respectively, and another specimen, 1700 mm. fork length, the measurements of which are given by Frade (1929: 236), has the dorsal and anal lobes nearly of the same length, 34 and 37, respectively. The dorsal and anal lobes of the latter two specimens are moderately higher than those of 24 similar-sized specimens from Angola (given in the tables), and closely approach the preceding western Atlantic specimen. It should be noted, however, that the comparison is not altogether fair as the measurements of the two western Atlantic specimens are based on photographs.

On the whole, considering the extant evidence from the western Atlantic, it may be reasonably concluded that large specimens of the western Atlantic yellowfin tuna have the dorsal and anal lobes considerably longer, at least on the average, than similar specimens from the eastern Atlantic. While the existing evidence is meager, nevertheless it shows that this population as compared with that from the eastern Atlantic, is entitled to separate nomenclatorial recognition; but the evidence is not of sufficient extent to make a final decision regarding the taxonomic category in which it is to be placed. To simplify matters a binomial is here used to designate this population, pending an adequate determination of its extent of divergence.

According to Poey the dorsal and anal lobes of his *subulatus* were much longer than the pectoral. It is evident, therefore, that Poey described a yellowfin tuna and his name *subulatus* takes precedence over *allisoni* of Mowbray.

Thunnus catalinae (Jordan and Evermann)

American Pacific Yellowfin Tuna

Neothunnus catalinae Jordan and Evermann, 1926: 19, pl. 4 (Santa Barbara Islands, Calif.; type, No. 597, Mus. Calif. Acad. Sci., a photograph of a fish taken off Catalina Island, Calif.).

An inspection of the data in Tables I and II shows that the eastern Pacific population diverges considerably from those of the western Pacific and eastern Atlantic in having shorter dorsal and anal lobes, in large specimens, but the data are insufficient to determine satisfactorily the precise degree of divergence. Nevertheless, it may be reasonably expected that adequate data will show that this population properly should be recognized nomenclatorially, especially as compared with the western Pacific population. Since this population already received formally a separate designation, it is best to continue this course. Pending the determination of adequate data, a binomial is here tentatively used to designate this population.

The name *catalinae*, which is nomenclatorially valid, is the only one proposed for the yellowfin tuna of the American Pacific coast and should be applied to this population although its original account is unsatisfactory.

Thunnus macropterus (Temminck and Schlegel)

Western Pacific Yellowfin Tuna

Thynnus macropterus Temminck and Schlegel, 1842, Fauna Japonica, p. 98, pl. 51 (Japan).

While the eastern Pacific yellowfin tuna apparently is nearest to that of the eastern Atlantic in the length of the dorsal and anal lobes, that of the western Pacific, including Oceania, seems to be nearest to the one in the western Atlantic in these measurements—both having comparatively long lobes in the larger specimens. Kishinouye (1923: 446) stated in his description of the Japanese population: "The second dorsal and the anal are much elongated, especially in the variety named itoshibi or gesunaga, the tips of these fins are whitish and reach to the base of the caudal." Jordan and Evermann (1926: 83) published a photograph of a large specimen from Hawaii with very long lobes (which they described as a new species, *itosibi*). Fowler (1933: 164) described and figured a large specimen from Tahiti with very long lobes (which he established as a new genus and species, *Semathunnus guildi*). Nichols and LaMonte (1941: 29) likewise published a photograph of two large specimens from Hawaii with very long fins. The data published by Godsil and Byers (1941: 48–49) would also seem to indicate that the western Pacific yellowfin has longer lobes as compared with that from the eastern Pacific. Their specimens were not large comparatively and their data are not well comparable in regard to the size of the fish. Their samples from Perú and Japan comprised the largest specimens, and although not altogether comparable as to size, those from Japan have distinctly longer lobes.

Judged strictly by the data in Tables I–II, the western Pacific yellowfin population diverges from that of the eastern Atlantic to a degree that is only of racial magnitude and is not entitled to separate nomenclatorial standing. However there are other factors to be considered: (1) Specimens of the two populations have not been directly compared as

Table I

quency Distribution of the Length of the Second Dorsal Lobe Expressed as a Percentage of the Standard Length, Segregated by Size Groups, of *Thunnus albacares* from Angola, *T. catalinae* from the Pacific Coast of Costa Rica, and *T. macropterus* from Hawaii

From the data published by Schaeffer (1948 and 1952) and Schaeffer and Walford (1950).

Species	Standard length, mm.	Length of second dorsal lobe												
		9–11	12–14	15–17	18–20	21–23	24–26	27–29	30–32	33–35	36–38	39–41	42–44	45–46
albacares	491	1	..	..	..	..	..	..	..	..	..	..	..	..
catalinae	542–662	5	2	..	..	..	..	..	..	..	..	..	..	..
macropterus	451–656	9	21	..	..	..	..	..	..	..	..	..	..	..
albacares	751–844	..	5	16	..	..	1	..	..	..	..	..	..	..
catalinae	693–897	..	8	3	..	..	..	..	..	..	..	..	..	..
macropterus	681–888	..	2	3	2	..	..	..	..	..	..	..	..	..
albacares	985–1133		..	1	2	..	..	..	..	..	..	..	..	..
catalinae	918–1132		5	11	2	..	..	..	..	..	..	..	..	..
macropterus	912–1134			9	16	1	..	..	..	..	..	..	..	..
albacares	1166–1381	..	..	..	5	10	6	2	..	..	..	..	..	..
catalinae	1144–1242	..	..	1	3	2	..	..	..	..	..	..	..	..
macropterus	1142–1399	..	..	1	2	17	13	15	2	..	..	..	..	..
albacares	1406–1626	..	..	..	..	2	3	4	..	..	1	..	..	..
catalinae	1411–1571	..	..	1	1	1	..	..	..	..	..	..	..	..
macropterus	1405–1621	..	..	..	..	4	5	10	9	8	3	3	..	..
macropterus	1629–1785	..	..	..	..	..	1	1	2	13	14	11	2	1

Table II

Frequency Distribution of the Length of the Anal Lobe in Three Species of *Thunnus*

Calculated as in Table I and from the same sets of data

Species	Standard length, mm.	Length of anal lobe														
		8–10	11–13	14–16	17–19	20–22	23–25	26–28	29–31	32–34	35–37	38–40	41–43	44–46	47–49	50–52
bacares	491	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
talinae	542–662	..	7	..	..	..	..	..	..	..	..	..	..	..	..	..
acropterus	451–656	8	23	..	..	..	..	..	..	..	..	..	..	..	..	..
bacares	751–844	..	..	20	2	..	..	..	..	..	..	..	..	..	..	..
talinae	698–897	..	4	5	1	..	..	..	..	..	..	..	..	..	..	..
acropterus	681–888	..	..	4	1	2	..	..	..	..	..	..	..	..	..	..
bacares	985–1133	..	..	1	1	1	..	..	..	..	..	..	..	..	..	..
talinae	918–1132	..	..	6	9	3	..	..	..	..	..	..	..	..	..	..
acropterus	912–1134	..	..	3	9	11	2	..	1	..	..	..	..	..	..	..
bacares	1166–1381	..	..	..	1	6	10	4	3	..	..	..	..	..	..	..
talinae	1144–1242	..	..	..	1	4	1	..	..	..	..	..	..	..	..	..
acropterus	1142–1399	..	..	..	1	4	14	14	13	3	1	..	..	..	..	..
bacares	1406–1626	..	..	..	1	..	1	3	2	2	..	1	..	..	..	..
talinae	1411–1571	..	..	..	..	2	..	1	..	..	..	..	..	..	..	..
acropterus	1405–1621	..	..	..	..	..	4	1	7	7	11	5	5	1	..	1
acropterus	1629–1785	..	..	..	..	..	..	..	3	2	11	6	13	7	2	1

yet. (2) Not all promising phases of the morphology of these two populations have been studied and compared. (3) They inhabit totally different faunal areas. Very few species are now considered to be common to both areas, and the adequacy of the treatment of even these few supposedly common species has not been firmly established as yet. Consequently, it is very probable that the two tuna populations concerned will eventually be found to belong to two distinct species. (4) Most authors have treated them as distinct species.

In view of these other factors and to avoid the possible confusion that might be caused by shifting names in and out of the synonymy, it seems best to continue to treat the two populations tentatively under separate binomial headings, as they have been treated generally heretofore, until adequate data are furnished to determine the question one way or the other. Likewise, the precise differences between the western Pacific and western Atlantic populations still remain to be determined.

Literature Cited

Beebe, William, and John Tee-Van. 1936. Systematic notes on Bermudian and West Indian tunas of the genera *Parathunnus* and *Neothunnus*. *Zoologica, 21 (3): 177–93, pls. 1–7.*

Chabanaud, Paul. 1930. Sur l'aisselle de lapectorale de divers poissons scombroïdes. *Bull. Soc. Zool. France, 55: 142–50.*

Cunningham, Joseph T. 1910. On the marine fishes and invertebrates of St. Helena. *Proc. Zool. Soc. London, 1910: 86–131, pls. 4–6.*

Fowler, Henry W. 1933. Description of a new long-finned tuna (*Semathunnus guildi*) from Tahiti. *Proc. Acad. Nat. Sci. Phila., 85: 163–64, pl. 12.*

Frade, Fernando. 1929. Sur quelques thons peu connus de l'Atlantique. *Bull. Soc. Portugaise Sci. Nat., 10 (20): 227–43, pl. 5.*

———. 1931a. Données biométriques sur trois espèces de thon de l'Atlantique Oriental. *Rap. Cons. Perm. Intern. Expl. Mer, 70: 117–26.*

———. 1931b. Données biométriques pour l'étude du thon rouge de l'Algarve. *Bull. Soc. Portugaise Sci. Nat. 11(7): 89–130, figs. 1–30.*

———. 1931c. Sur le nombre de rayons des nageoires et de pinnules branchiales chez le thon rouge Atlantique. *Ibid.: 139–44.*

Fraser-Brunner, A. 1950. The fishes of the family Scombridae. *Ann. Mag. Nat. Hist., (12) 3: 131–63, figs. 1–35.*

Ginsburg, Isaac. 1952a. Flounders of the genus *Paralichthys* and related genera in American waters. *U. S. Fish and Wildlife Serv., Fish. Bull. 71: 267–351.*

———. 1952b. Fishes of the family Carangidae of the northern Gulf of Mexico and three related species. *Publ. Inst. Mar. Sci. Univ. Texas, 2 (2):* 43–117.

Godsil, Harry C., and Robert D. Byers. 1944. A systematic study of Pacific tunas. *Calif. Div. Fish and Game, Fish Bull. 60: 1–131, figs. 1–76.*

Godsil, Harry C., and Edwin K. Holmberg. 1950. A comparison of the bluefin tunas, genus *Thunnus* from New England, Australia and California. *Ibid., 77: 1–55, figs. 1–15.*

Heldt, Henri. 1927. Contribution a l'étude des races de thons. *Ann. Sta. Océan. Salambô, 4: 1–54, figs. 1–43.*

———. 1931. Thunnus thynnus. *In*: Fauna Ichthyologique de l'Atlantique Nord. *Cons. Perm. Intern. Expl. Mer, No. 7.*

Herre, Albert W. 1936. Fishes of the Crane Pacific Expedition. *Publ. Field Mus. Nat. Hist. (zool. ser.), 21: 1–472, figs. 1–50.*

Jordan, David S., and Barton W. Evermann. 1926. A review of the giant mackerel-like fishes, tunnies, spearfishes and swordfishes. *Occ. Pap. Calif. Acad. Sci., No. 12: 1–113, 20 pls.*

Kishinouye, Kamakichi. 1923. Contributions to the comparative study of the so-called scombroid fishes. *Jour. Coll. Agr. Imp. Univ. Tokyo, 8 (3): 293–475, pls. 13–34, figs. 1–26.*

Marr, John C., and Milner B. Schaefer. 1949. Definitions of body dimensions used in describing tunas. *U. S. Fish and Wildlife Serv., 51, Fish. Bull. 47: 241–44.*

Nichols, John T., and Francesca R. LaMonte. 1941. Yellowfin, Allison's and related tunas. *Ich. Contr. Int. Game Fish Assoc., 1 (3): 25–32, figs. 1–3.*

Rivas, Luis Rene. 1951. A preliminary review of the western north Atlantic fishes of the family Scombridae. *Bull. Mar. Sci. Gulf Carib., 1 (3): 209–30.*

Schaefer, Milner B. 1948. Morphometric characteristics and relative growth of yellowfin tunas (*Neothunnus macropterus*) from Central America. *Pacific Science, 2 (2): 114–20.*

———. 1952. Comparison of yellowfin tuna of Hawaiian waters and of the American west coast. *U. S. Fish and Wildlife Serv., Fish. Bull. 72: 353–73.*

Schaefer, Milner B., and Lionel A. Walford. 1950. Biometric comparison between yellowfin tunas (*Neothunnus*) of Angola and of the Pacific coast of Central America. *U. S. Fish and Wildlife Serv., Fish. Bull. 56: 425–43.*

Walford, Lionel A. 1937. Marine game fishes of the Pacific coast from Alaska to the Equator. *Univ. Calif. Press, Berkeley, XXIX + 205 pp., frontis. and 69 pls. (37 colored).*

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ICHTHYOLOGY.—*Ten new American gobioid fishes in the United States National Museum, including additions to a revision of* Gobionellus.

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During revisional studies of the genera of American fishes, the following 10 undescribed species and subspecies discovered in the U. S. Fish and Wildlife Service and the U. S. National Museum are here named and briefly described. All holotypes are deposited in the National Museum.

Figures of proportional measurements given below refer to percentages of the standard length. Lengths of the pectoral and ventral fins denote the length of their longest rays, from their point of articulation, as determined at the surface without dissection, to their distal margin. The given lengths of specimens refer to the total length, including the caudal fin, unless otherwise stated.

The numbers of fin supports are of paramount importance in the classification of fishes, including gobies. The precise structure of the fins of fishes in general, namely, the different kinds of fin supports comprising the fins, differs largely by family or other major taxonomic groupings. The variability and relative numbers of the different supports differ by species or population of lower rank, and also by higher taxonomic groups. The numbers of fin supports have been widely used in taxonomy; but the broader problem of the comparative morphology of the fins of fishes in general has been largely neglected. Lately, this subject began to engage the attention of investigators. Hubbs (Copeia, 1943: 134; 1945: 75) raises the question of the use of a certain fin formula in describing gobioid fishes, in connection with a discussion of the structure of the fins of other fishes. Beebe (Zoologica **27:** 45. 1942) is of the opinion that the last two approximated dorsal rays of *Dixonina*—a genus belonging to a different order than gobies—and related genera should be enumerated separately instead of counting them together as one ray. However, a thorough study of the comparative morphology of the fins in the major groups of fishes still remains to be made. As the fin structure differs largely by major groups, the proper and most advantageous method of enumeration, and any formula expressing such enumeration, will differ by such major groups.

In the superfamily Gobioidea the structure of the fins is as follows: The first dorsal consists of flexible (with few exceptions), unsegmented fin supports which are evidently homologous with the pungent spines of other fishes having two dorsal fins. The first fin support of the second dorsal is, as the fin supports of the first dorsal, likewise flexible and unsegmented, and is presumably also homologous with the pungent spine in the same position of other fishes (although no thorough study has as yet been made to verify this assumption). The first unsegmented fin support of the second dorsal is followed by a variable number of segmented, and variously branched rays, the last two of which are very closely approximated at the base. The structure of the anal is the same as that of the second dorsal.

The above described structures apply to all the species in the superfamily and virtually to all the individuals of any species. Exceptions from the general rule that are now and then found in individual fish—and such exceptions comprise less than 1 percent of the combined counts of all the species examined—are to be considered as slight abnormalities rather than as representations of a normal individual variability. As these are superfamily characters, there seems no point in repeating these facts under each species, either in words or by a formula, as it is unnecessary to repeat any other superfamily character in the species descriptions. Consequently, in the descriptions here given the following uniform method is adopted in enumerating those rays that are of importance in separating the species: All counts are given in Arabic numerals. A semicolon separates the counts of the two dorsals and a hyphen connects the extremes of the range of the count of any given fin. The first unsegmented fin support of the second dorsal, and anal, is included in the count, while the last two approximated rays of both fins are counted as one. This is the method I used uniformly in previous publications on gobioids. If it is desired to get the number of segmented rays only, that is, to exclude the first fin support and count the last two as one ray, 1 is to be subtracted from the figures given below; to include the first and count the last two separately, 1 needs to be added; excluding the first and counting the last two separately, the numbers will be the same as those given below.

The rays in the pectoral fin of gobies generally do not differ in essential structure, except that some of the marginal rays grow progressively shorter, and the extent of branching decreases outwardly. In the following descriptions all the pectoral rays are included without distinction in the same count.

Family Eleotridae

Dormitator cubanus, n. sp.

D 7; 8–9. A 8–9. P 15. Sc 33–35. No mucous pores on preopercular sulcus. Total number of gill rakers in outer row of first gill arch, in a 94-mm specimen, 29. Head 30–31, postorbital part of head 15.5–16.5, caudal 27–28, ventral 23.5–24.5, pectoral 23–25.5. Body with a median longitudinal row of very diffuse spots; a dark shoulder spot above pectoral base; a dark, narrow, short, oblique band on cheek, under anterior margin of pupil to end of maxillary; the two dorsals and caudal with rows of small dark spots, roughly transverse on caudal and oblique on dorsals. (No oblique transverse light bands on body against a darker background as in related species, but their absence possibly due to fading.)

Holotype.—U.S.N.M. no. 55668. San Cristóbal, Cuba; C. H. Eigenmann; 1902; female 82 mm.

Paratypes.—U.S.N.M. no. 123234, a male obtained with the holotype, 73.6 mm in standard length with the caudal broken, approximately 94 mm in total length. U.S.N.M. no. 55688; Pinar del Río, Cuba; C. H. Eigenmann; March 1902; female 48 mm.

Remarks.—This is a well-marked species and differs sharply from its congeners in the number of gill rakers. Specimens of comparable size, with that stated above, of the other species have a total of 51 or more gill rakers in the outer row of the first gill arch. It also differs in lacking pores on the preopercular sulcus, and in averaging fewer dorsal and anal rays and shorter fins; although there is more or less intergradation in these latter characters. Taking its character pattern as a whole, *cubanus* is sharply defined and rather easily distinguishable. It is probably a highly localized species and confined to some fresh-water streams in Cuba, as 445 specimens of *Dormitator* examined from the western Atlantic coasts, ranging from Texas to Brazil, and from several West Indian Islands including Cuba, all belong to the common Atlantic species, *maculatus*.

The three specimens forming the basis of this account were collected by Eigenmann (Bull. U. S. Bur. Fish. **22** (1902): 211–236. 1903) during his investigation of the cave inhabiting fishes of Cuba, in 1902, when he made many striking discoveries. He then obtained both *maculatus* and *cubanus* and recorded them together under the former designation.

Dormitator latifrons mexicanus, n. subsp.

D(6) 7 (8); (8) 9–10. A (9) 10–11. P 14–16. Sc 34–36.—Preopercular sulcus with pores, usually 4 in number. Total number of gill rakers in outer row of first gill arch, in 3 specimens 242–256 mm (from Colima, Mexico), 132–145, and in the same specimens, head 30.5–32.5, postorbital 16–18, caudal 30.5–32.5, ventral 20–22, pectoral 22.5–24. In the holotype, gill rakers 107, head 33, postorbital 19, caudal 34.5, ventral 21.5, pectoral 25.5. Body dark with rather narrow, obliquely transverse, diffuse, lighter cross bands; a large very dark shoulder spot near and over pectoral base; a narrow dark band on cheek under anterior margin of pupil to end of maxillary; posterior part of head with dark longitudinal, nearly parallel bands, rather faint to well defined; a somewhat curved band at pectoral base.

Holotype.—U.S.N.M. no. 7350. San Lucas, Lower California; I. Xanthus; male 140 mm.

Remarks.—Other 49 specimens 24–256 mm examined from the Pacific coast of Mexico ranging from La Paz in the Gulf of California to Salina Cruz in the gulf of Tehuantepec.

The subspecies *mexicanus* differs from *latifrons* chiefly in the number of gill rakers and the head length. Both of these characters differ also intraspecifically with the size of the fish and it is necessary to compare specimens of like size. Two specimens of *latifrons* from the Pacific coast of Panamá, 235–259 mm, comparable in size with the large specimens described above, have gill rakers 149–164 and head length 33.5–38. *D. mexicanus* also averages a shorter caudal, ventral, pectoral and postorbital part of the head; but it intergrades considerably with *latifrons* in these characters. The two are apparently allopatric populations on the Pacific coast of Mexico and Central America, respectively. In this preliminary account the few largest specimens are compared and they do not show intergradation in the two chief characters. However, a comparison of the 50 specimens examined of *mexicanus* with 47 specimens of *latifrons*, segregated by comparable size groups shows that they intergrade with a degree of divergence of subspecies magnitude.

The name *latifrons* was proposed by Richardson for two specimens from the "Pacific Ocean." It has since been used for the common eastern Pacific species of *Dormitator*, including Mexico and Central America, or the name was placed in the synonymy of *D. maculatus*, depending on whether an author treated the eastern Pacific population as a distinct species, or he treated that population as being conspecific with that from the western Atlantic. As the common eastern Pacific species is here divided into two subspecies, the name *latifrons* is hereby restricted to the Panama population, since it is more likely that Richardson's specimens came from the coast of central America than that of Mexico.

Guavina micropus, n. sp.

D 7; 10. A 10. P 16. Sc 89. Almost completely scaled, except underside of head, and preopercular sulcus, and a small area on side of snout in front of eye, altogether or largely scaleless. Scales on posterior part of body rather weakly spinulose, others cycloid. Ventral 11.5, pectoral 16, body depth 22.5, least depth of caudal peduncle 15, head 31, postorbital 18, head depth directly behind eye 15, head width at same point 20, maxillary 13, snout 9, eye 5.5, interorbital 10.5, antedorsal distance 36.5. Color brownish, dark on dorsal aspect, much lighter below; no saliently distinctive markings, pigment somewhat concentrated on upper part of pectoral base forming a rather faint, diffuse blotch.

Holotype.—U.S.N.M. no. 123230. Miraflores Locks, Panama Canal; east chamber; A. O. Foster; April 28–29, 1937; female 90 mm in standard length, the caudal damaged.

Remarks.—Only one species of this genus was known heretofore, *G. guavina* from the western Atlantic coasts. The new species differs at a glance in having a strikingly short ventral fin, which also shows up well after measuring, 10 specimens of *guavina* having the ventral 18–19.5. This species also has a shorter pectoral and antedorsal, but these differences are not as great as that of the ventral; in the same 10 specimens of *guavina*, pectoral 20.5–22, antedorsal 39.5–41.5. It also has one ray less in the dorsal (in the specimens examined of *guavina*, the dorsal rays are constantly 11), and it further differs in having the preopercular sulcus naked instead of scaled over.

This is most probably a hitherto undiscovered Pacific species, corresponding to the Atlantic *guavina*, which has found its way into the Panama Canal.

Gobiomorus polylepis, n. sp.

D 6; 10. A 10. P 18. Sc 77–78. Caudal 24.5, entral 18.2–18.4, pectoral 17.8–18, depth about 0 (belly collapsed and not accurately determinable), peduncle 11.5–12, head 30–30.5, postorbital 18–18.1, head depth 12.3–12.4, head width 14.7–14.8, maxillary 12.5–13, snout 9.5–0, eye 3.4–3.8, interorbital 7–7.5, antedorsal 36.5–37. Irregularly shaded, without distinctive markings (perhaps faded from long immersion in preservative); pectoral, caudal and the two dorsals with rows of small diffuse spots.

Holotype.—U.S.N.M. no. 130917. Colima, Mexico; exhibited by Mexican Government at Chicago World's Fair, 1893; female 277 mm, 222 mm in standard length.

Paratype.—U.S.N.M. no. 123233; from same container as the type; female 243 mm in standard length with caudal end broken off, approximately 303 mm in total length.

Remarks.—Two common and widespread species of *Gobiomorus* were known heretofore, *maculatus* from the Pacific drainage and *dormitor* from the Atlantic drainage. In preparing a revision of the genus, *polyelpis* was compared with 257 specimens of *maculatus* from localities ranging from the Gulf of California to Peru, including 14 specimens from the coast of Mexico, and 204 specimens of *dormitor* ranging from Texas to Venezuela. This is a strongly marked species and is easily distinguishable from the two common species by the number of scales. In 175 specimens of *dormitor* the range of the scale count is 58–64, in 241 specimens of *maculatus* the range is 54–60, as compared with 77–78 in *polylepis*. In the number of anal and pectoral rays, *polylepis* nearly agrees with the Atlantic *dormitor*, rather than with the Pacific *maculatus*, and in the number of scales it is also nearest *dormitor*. It is remarkable that such a sharply defined and large gobioid species from the North American continent escaped detection up to now. It is probably another one of those species having a narrowly circumscribed geographic range.

Erotelis smaragdus civitatum, n. subsp.

D 6; 12. A 10. P 17. Sc 105. Scales on dorsal aspect extending to within a short distance of eyes; opercle entirely scaleless; cheek almost naked, only a few scales present posteriorly near its middle; all scales cycloid. Preopercular spine rather reduced and concealed under the skin. Caudal 27.5, ventral 13, pectoral 15.5, depth 15, peduncle 10, head 20.5, postorbital 13.5, head depth 9, head width 9.5, maxillary 7.5, snout 4.2, eye 3.2, interorbital 4.3, antedorsal 32.5. Color almost uniformly dusky, darker on dorsal and somewhat lighter on ventral aspect; pigment somewhat concentrated on upper part of pectoral base to form a diffuse blotch; otherwise no distinctive color marks.

Holotype.—U.S.N.M. no. 123229. St. Vincent Island, Fla.; taken with seine in deep soft mud in large pond on the bay side of the island; Isaac Ginsburg; July 23, 1932; female 123 mm.

Remarks.—The above description is drawn from the holotype. Two small specimens 46–57 mm from Harbor Island, Tex., collected by John C. Pearson, have the following counts: D 6; 12. A 10. P 18. and D 6; 11. A 10. P 17.

This subspecies differs from *smaragdus* chiefly in the number of dorsal rays. In 26 specimens of *smaragdus* the dorsal rays number 11 in 25 and 10 in 1. In 11 specimens of the Pacific *armiger* the dorsal rays number 13 in 9 and 12 in 2. The dorsal count in *civitatum,* 12 in 2 specimens and 11 in 1, is intermediate between *smaragdus* and *armiger*. While only 3 specimens of *civitatum* are available, fair composite samples of *armiger* and *smaragdus* were examined to show that it diverges at least subspecifically from the latter. The samples examined indicate a divergence of subspecies degree. In general appearance, *civitatum* is not as excessively slender as *smaragdus* which is almost anguilliform, but somewhat approaches in this respect the species of the closely related genus *Eleotris*. This difference is rather marked on direct comparison of specimens, but does not show up well in measurements.

Of the 26 specimens of *smaragdus* examined 7 are from Key West, the others are from Cuba, Haiti, Puerto Rico, Curaçao, Panamá, and Venezuela. Consequently the Key West population of *smaragdus* is nearer to those of the West Indies and Central America than to that on the northern Gulf coast of the United States.

Chriolepis tagus, n. sp.

D 7; 12. A 11. P 19. Anterior part of body naked, posterior part scaled, scales extending forward to under end of first dorsal; caudal base with modified scales. (The single specimen described is in but indifferent condition, the squamation especially is defective and nearly all scales have fallen. The scale pockets indicate the extent of squamation. On the caudal base only one scale is now remaining, at its outer angle, a conspicuously modified, large ctenoid scale, very similar to the scale present in *Chriolepis minutillus* in the same position.) Lower jaw with two inner posterior caninoids. Eye large, the interorbital narrow. Ventral falling considerably short of anus. Pectoral reaching beyond a vertical through origin of first dorsal. Tongue moderately emarginate. (Color apparently faded, only a few large scattered chromatophores on head.)

Holotype.—U.S.N.M. no. 123232. Tagus Cove, Albemarle Island, Galápagos Archipelago; dredged in 10–18 fathoms; Hancock Expedition, W. L. Schmitt; January 15, 1934; male 16.3 mm in standard length, 21 mm to end of partly broken caudal.

Remarks.—The squamation is more extensive in this species than in any known species of *Chriolepis*. The number of anal and pectoral rays is higher than in any other species. The number of dorsal rays is higher than in any species, except some individual variants of *minutillus*. Altogether, *tagus* is a sharply divergent and strongly marked species.

Chriolepis benthonis, n. sp.

D 7; 9. A 8. P 16. Anterior part of body naked, posterior part scaled; scales extending forward to a point near midline under base of seventh dorsal ray; in 12 oblique rows to base of caudal; a few scales on posterior part of peduncle ctenoid, most scales cycloid; modified scales on caudal base present (most modified scales missing and cannot be described in detail). Lower jaw without posterior inner caninoids. Eye very large; interorbital very narrow. Ventral reaching anus. Pectoral reaching to under base of first dorsal ray. Tongue entire. Ventral 28.5, pectoral 27.5, depth 21, peduncle 12, head 30.5, postorbital 14.5, head depth 17, head width 19, maxillary 12, snout 8, eye 10.5, interorbital 2, antedorsal 37.5. (Color a rather uniform light yellowish, probably faded.)

Holotype.—U.S.N.M. no. 47641. *Blake* Expedition, station CCXLI, Alexander Agassiz; off Progreso, Yucatán, Mexico; lat. 23° 13′ N., long. 89° 10′ W.; 84 fathoms; male 30.7 mm in standard length, the caudal damaged.

Remarks.—This species has the lowest number of dorsal and anal rays of any known species of *Chriolepis*. The extent of scalation is nearly as in the Pacific *zebra*; it differs from that species, besides the difference in the number of dorsal and anal rays, also in having smaller teeth, a larger eye and narrower interorbital.

Psilotris, n. gen.

Genotype.—*Psilotris alepis*, n. sp.

This genus is characterized by and differs from all known American eleotrid genera, by a combination of two characters: the total lack of scales and the absence of mucous pores. Full grown specimens of *Eleotrica* also lack scales; but *Psilotris* differs in lacking pores as well. A detailed study of American gobioids leads to the conclusion that the character of the pores is more important as a phylogenetic criterion than the character of the squamation. It follows then that *Psilotris* is more nearly related to *Chriolepis* which also lacks pores, although the latter has the body partly scaled. With respect to the squamation, and other characters as well, *Psilotris* and *Chriolepis* present a closely analogous, parallel development to the genera *Gobiosoma* and *Garmannia* in the family Gobiidae.

Etymology.—*Psilotris*, an abbreviated form of psiloeleotris (naked eleotris).

Psilotris alepis, n. sp.

D 7; 10. A 9. P 15. Scales altogether absent, on caudal base as well as on the body and head. Body moderately elongate, compressed; head moderately depressed. Maxillary ending under anterior margin of pupil. Mouth subterminal, lower jaw but slightly projecting; gape very moderately inclined, a horizontal through distal margin of upper lip passing through lower part of eye. Teeth in bands; outer teeth well enlarged; inner posterior teeth in lower jaw also enlarged, but hardly large enough to be described as caninoid. Ventral falling considerably short of anus; pectoral slightly short of a vertical through base of first dorsal ray. Gill opening restricted, attachment of branchiostegal membrane near lower part of pectoral base. Female anal papilla large, thick, globose. No mucous pores on head. Caudal 27.5, ventral 23.5, pectoral 27.5, depth 23.5, peduncle 13.5, head 30.5, postorbital 18, head depth 16, head width 17.5, maxillary 11.5, snout 7, eye 7, interorbital 3, antedorsal 42.5. (Because of the very small size of the specimen measured, and the comparative crudeness of the instrument used, an ordinary Vernier caliper, the preceding measurements are rough approximations only.) Diffusely cross-banded; body with 5 broad, irregular, diffuse bands, the anterior 2 somewhat Y-shaped; a subvertical, diffuse band under anterior part of eye; a wider, oblique band under posterior part of eye.

Holotype.—U.S.N.M. no. 123231. St. Croix land, Virgin Islands; on reef; Smithsonian Hart-rd Expedition, W. L. Schmitt; April 8, 1937; male 17 mm. The small specimen examined ppears to be an adult. It apparently represents very small species, rather than the young of a rger species.

This species is readily distinguished from all nown western Atlantic eleotrids by its total ck of scales. Its relationship is discussed above nder the genus account.

Family Gobiidae

Genus **Gobionellus** Girard

Since my revision of this genus was published Bull. Bingham Oceanogr. Coll. **4** (art. 2). 1932), had the opportunity to study many more amples of nearly all species, comprising for most pecies many more specimens than those forming he basis of the revision. Besides the additional pecimens examined, characters hitherto generlly neglected and not considered in the revision, ave been studied in detail. The more striking esults of this study of additional samples and haracters are as follows: (1) Two new species vere discovered. (2) It was concluded that two merican species, previously described and eferred to *Euctenogobius*, are more properly laced in *Gobionellus* as their character pattern, n general, fits in well with the other species of he latter genus. (A discussion of the status of *uctenogobius* has been published by me in roc. U. S. Nat. Mus. **82:** 19. 1933.) (3) The elationship of one species as treated in the reision, needs emendation. The two new species re here described, and also three new subgenera re established, in accordance with the addiional information to place all species in their roper place in the scheme of classification emloyed in the revision.

Gobionellus mystax, n. sp.

D 6; 13. A 14. P 17–19. Sc 70–73. Scales exending on antedorsal area to a vertical plane hrough preopercular sulcus, a narrow naked rea on midback, corresponding to predorsal eel, extending from origin of first dorsal, all the vay forward; dorsal area in front of preopercular ulcus, and side of head scaleless; throat largely aked, except a rather narrow longitudinal edian strip of scales; pectoral base scaleless; entral aspect of belly scaled, except a rather oderate naked area directly behind base of ventral fin; anterior scales and those on belly cycloid, posterior scales nearly all ctenoid, the ctenoid scales beginning at a point near midline under base of fourth dorsal spine. Teeth in narrow bands, those in outer and inner rows only a little larger than others. Second and third dorsal spines in male notably prolonged, the third longest, reaching base of fifth dorsal ray. Maxillary notably long, its end reaching preopercular margin or nearly so. Caudal 55.5–57.5, ventral 20.5–21, pectoral 19, depth 16–17, peduncle 9–9.5, head 22, postorbital 10.5–11, head depth 13, head width 11–11.3, maxillary 15.5–16, snout 8–8.5, eye 4.5, interorbital 3.5–4, antedorsal 29. (Color dark all over without distinctive markings, probably the color pattern obliterated from long immersion in preservative.)

Holotype.—U.S.N.M. no. 130859. Laguna de Mexcaltitan, Territory of Tepic [now the state of Nayarit], Mexico; exhibited by Mexican Government at Chicago World's Fair, 1893; male 227 mm, 144 mm in standard length.

Paratype.—U.S.N.M. no. 123235. In same lot with the type; male 251 mm, 161 mm in standard length.

Remarks.—This species is close to *microdon* and belongs in the same subgenus with it, *Gobatus.* It differs in having a longer maxillary and caudal. In the genus *Gobionellus* both of these characters differ with the species and also intraspecifically with sex and size, the caudal considerably and the maxillary moderately so. As the two specimens examined are very large males, it may be suggested that the seemingly specific differences are rather due to their size and sex. However, they were compared with a male of *microdon* 117 mm in standard length from Miraflores Lake, Panama Canal, not much smaller than the two specimens here described, and the differences in these two characters are too pronounced to be reasonably ascribed to intraspecific individual variability or sex and size differences. They are evidently interspecific differences and the two specimens represent a species close to but different from *microdon.* In the above male of *microdon*: caudal 34; maxillary 12.5, ending under posterior margin of eye. The maxillary in *mystax* is so strikingly long that the generic definition given in my revision of the genus needs to be emended to include this species.

The scales in the two specimens of *mystax* number 70–73, while in the two types of *micro-*

don from Río Ahome, México, they number 60–61, and it would seem that the two species also differ in the scale count. However, in two specimens of *microdon* from Río Juan Diaz, Panamá, the scales are 59–65, while in two from the Panama Canal they number 69–72. Consequently, the scale count in *microdon* seems to differ intraspecifically with the population, and its possible value as an interspecific character remains to be determined by more extensive samples.

Gobionellus gracillimus, n. sp.

D 6; 14. A 15. P 18–20. Sc 83–99. Antedorsal area completely scaled to within a short distance of eyes; opercle with a moderate-sized patch of scales at upper anterior corner; cheek naked or a few scales present; throat partly scaled; pectoral base scaleless; ventral aspect of belly scaled over posteriorly, a rather large or moderate sized area behind base of ventral fin naked; anterior scales cycloid, posterior scales mostly ctenoid, the ctenoid scales beginning at a point variably situated under base of third dorsal spine to under base of fifth dorsal ray. Teeth in narrow bands, those in outer and inner rows a little larger than those in between. Maxillary generally ending under space between posterior margin of pupil and that of eye, slightly past eye in the largest males. Second to fourth dorsal spines notably prolonged in large specimens, the longest spine usually reaching to base of fifth or sixth dorsal ray, sometimes to base of third ray. Body notably slender and caudal notably long; depth 11.9–15.5 in female, 11–13.3 in male; caudal 41–46.5 in female, 51.5–63.5 in male. Other measurements not of paramount specific importance and only slightly or moderately different with sex, the range of both sexes as follows: ventral 17.5–21.5, pectoral 16.0–20.5, peduncle 7.5–9, head 18–21.5, postorbital 8.5–11.5, head depth 10.5–13, head width 9–10.5, maxillary 9.5–11.5, snout 6.5–7.5, eye 3.5–5, interorbital 2–3, antedorsal 25–29.5. (All preceding measurements, including that of caudal and depth, of specimens 106–165 mm in standard length.) A large, longitudinally oblong, dark spot below first dorsal and centered slightly above middle of body; a small spot on caudal base; 2 or 3 small dark spots on anterior margin of first dorsal; a median longitudinal row of many small spots, well marked in a recently preserved specimen, now faded, and not discernible in other preserved specimens; the large body spot and the caudal spot rather well marked in the smaller specimens, faint or imperceptible in large ones (color pattern seemingly becoming faint with growth and also fading in preserved specimens).

Holotype.—U.S.N.M. no. 123227. Apalachicola Bay, Fla.; trawl; July 16, 1932; Isaac Ginsburg; male 271 mm, 165 mm in standard length.

Remarks.—Thirteen other specimens 106–157 mm in standard lengths were studied from St. Johns River, New Smyrna, and Pensacola Bay, Fla.; Bayou St. Denis, La.; off Padre Island, Tex.

In the revision of the genus, the populations of the extremely long bodied, western Atlantic gobies which belong to the subgenus *Gobionellus*, were divided into two species on the basis of the scale count, *hastatus* with more numerous scales from the northern Gulf coast, and *oceanicus* with fewer scales from Key West, the West Indies, and Central America. On the basis of the samples examined for the revision of the genus, the two species showed both a morphologic and geographic gap between them. Hildebrand and Cable later found that their geographic ranges overlap and that both species occur at North Carolina (Bull. U. S. Bur. Fish. **48:** 365. 1938). By an examination of many more specimens, I now find that these two species also intergrade somewhat in the scale count and are not as easily separable as the smaller samples indicated. Furthermore, I now find that the finer scaled gobies from the coast of the United States (58 specimens were now examined instead of the 7 specimens examined for the revision), fall into two groups, rather roughly separable by four correlated characters. One group, here distinguished as *gracillimus*, has a longer caudal, more slender body, longer dorsal spines and more numerous scales. The data for the four characters seem to form four bimodal curves, and we are evidently dealing with two distinct populations, *gracillimus* and *hastatus*. However, they intergrade in all four characters and individual specimens cannot always be placed with certainty. If a specimen has all four, or at least three, of the characters typical or close to the mode of its population, it can be placed with a measure of assurance, and this is so with the large majority of specimens. But, if a specimen has less than three characters correlated, or if three or four of its characters fall near the borderline its proper position is doubt-

. (Such doubtful specimens constitute approxi- tely 10 percent of the total.) Consequently, e proper taxonomic status of these two evi- ntly distinct populations is uncertain. If they re to occupy separate geographic ranges, they ould properly be treated as two geographic bspecies, and such a course could hardly be estioned. As it is, they either constitute two ordinate, synpatric subspecies, in which case ey form an exception to the general rule that o subspecies occupy separate territories, per- ps they are ecological subspecies having nearly e same geographic range; or they constitute o full species which are but incompletely dis- guishable by current taxonomic methods. ese questions might be resolved by a more borate sampling of the populations, perhaps pplemented by ecological studies. The distin- ishing characters, except the scale count, dif- r also with size and sex, and hence it would take ry extensive samples to work out the finer tails.

Large males, 120 mm or over in standard gth, diverge most, and such specimens are ll separable by species.

It is probable that depth of water is a factor the distributional basis of the separation of e two species. Detailed records of capture are nting or incomplete for most of the con- ituent samples examined. But judged by the ailable records, it seems that *gracillimus* is ually taken with a trawl, while *hastatus* is ken with a seine as often as with a trawl. How- er, neither species is a real deep water fish. he greatest depth recorded is 10 fathoms for a ecimen of *gracillimus* taken off Padre Island, ex. Eight of the 14 specimens of *gracillimus* amined, comprising 5 constituent samples, ere taken in Pensacola Bay and that body of ater seems to be the center of distribution of e species.

Gobidus, n. subgen.

Genotype.—Gobionellus longicaudus (Jenkins d Evermann) = *Gobius longicaudus* Jenkins d Evermann.

Before this subgenus is characterized, two new mbols are herewith proposed to be used for o mucous pores placed over the opercle. In nzo's (Mitth. Zool. Stat. Neapel **20:** 251–328. 11) system of symbols for the various parts of e lateral line organs of gobies, the anterior d posterior pore which form the openings of the mucous channel over the opercle, are designated as ρ' and ρ'', respectively. His symbols for these pores are rather cumbersome, somewhat confusing, and to a certain extent misleading in that those two pores are often present or absent independently of ρ, at least I find it so in the American species. The symbols θ and τ are, therefore, here proposed to designate the anterior and posterior pore, respectively.

Extreme groups of species of *Gobionellus* are sharply distinguished by three striking characters, in addition to others. Those of the subgenus *Gobionellus* have a notably long and slender body, small scales, and they possess θ and τ; while those of *Gobica* have a body more like the usual gobiid shape, large scales and they lack θ and τ. The subgenus *Gobidus* lacks θ and τ like *Gobica*, its scales are nearly as in *Gobionellus*, while the body shape is rather intermediate or nearer to *Gobionellus*. Its dorsal spines are not at all prolonged and shorter than in any other subgenus, except *Congruogobius*. In the revision, the species of this subgenus was included with *microdon* in the subgenus *Gobatus*, largely on the basis of the scale and fin ray counts. However, the latter has θ and τ, and in other characters as well is much nearer the subgenus *Gobionellus*. *Gobidus* essentially agrees with *Gobica* in the lateral line organs and the color pattern, and in spite of superficial appearances, it is nearer to that subgenus than to *Gobatus*.

Gobionellus longicaudus has generally been placed by authors in the synonymy of *sagittula*, and in the revision of the genus I disposed of that name in the same manner; but the study of additional samples and characters show that the Mexican *longicaudus* and the Panamanian *sagittula* diverge markedly in the number of pectoral rays (a character not studied in detail in the revision) and scales, although they intergrade to some extent and may perhaps be treated as coordinate geographic subspecies. Without a definite commitment as to the taxonomic rank of *longicaudus* for the present, I prefer to designate it as the genotype of *Gobidus* because I have examined the type specimens and am certain of its position, while *sagittula* I identify only from its description.

Gobatinus, n. subgen.

Genotype.—Gobionellus panamensis (Meek and Hildebrand) = *Euctenogobius panamensis* Meek and Hildebrand.

This subgenus also is in a sense intermediate between the two groups noted above in that it has a combination of important characters of both groups, but in a manner reverse from that of the subgenus *Gobidus*. The scales are large (34–37) as in *Gobica*, while it has θ and τ like *Gobionellus*. The body shape is intermediate between that of the last two named subgenera. *Gobatinus* has the teeth in the upper jaw usually in one row, sometimes a second incomplete inner row is present. In the other subgenera, the teeth in the upper jaw are in 2–5 rows, depending on the subgenus.

Congruogobius, n. subgen.

Genotype.—Gobionellus liolepis (Meek and Hildebrand) = *Euctenogobius liolepis* Meek and Hildebrand.

This subgenus differs from all others in having the two dorsal fins confluent and the scales cycloid, except that the scales on a narrow strip along a median area on the posterior part of the body are weakly ctenoid or cycloid. In these two characters it is somewhat intermediate between the genera *Gobionellus* and *Gobioides* but much nearer the former. Indeed, *Gobionellus* and *Goboides* are nearer in relationship than has been heretofore suspected. This is shown not only by the somewhat intermediate positions occupied by the subgenus *Congruogobius*, but by other characters as well, especially by the lateral line organs, a discussion of which would take us too far afield here. The scales in *Congruogobius* are 77–84; θ and τ are present. In the latter two characters, as well as in the shape of the body and the number of fin rays, it nearly agrees with or is nearest to the subgenus *Gobionellus*. The interorbital is rather wide as in the subgenus *Gobionellus*, while the eye is even smaller than in that subgenus when specimens of the same size are compared. In the latter two characters it also somewhat approaches *Gobioides*.

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INTRODUCTION

The present state of the taxonomy of the western Atlantic scorpaenids leaves much to be desired. The literature is filled with inadequate original or supplementary descriptions of species, containing many unessential details of little or no practical use for the correct determination of the species, while the critical characters that distinguish the species often are not considered adequately. I found it well-nigh impossible to identify and distinguish the species properly by the use of current accounts. One of the main factors that operate to bedevil the taxonomist who conscientiously tries to identify his specimens is the undue multiplication by past authors of the number of fictitious species. Such untenable "species" have been established, in large measure, as a result of failure to elaborate properly, or even to take into consideration, the intraspecific range of variability of taxonomic characters, or their change with growth which, in the scorpaenids, is considerable. The multiplication of names that have been proposed for scorpaenid species that have no existence in fact is as confusing as the grouping of two or more closely related species under one name that has entered into the literature of other families.

As a result of this study it was found necessary to reduce to synonymy here for the first time 18 names that have been proposed for supposedly new species, all except one within the past 40 years. The type specimens of 13 of these nominal species have been examined and compared. The other five names are placed in synonymy on the basis of the original descriptions. Three of these descriptions include unique specific characters that indicate their proper placement with assurance, while the other two do not include enough details to make certain their position until the original specimens are reexamined. Where a name is reduced to synonymy the reasons for doing so are discussed under the accounts of the several species concerned.

One doubtful species, *Scorpaenodes floridae,* is here tentatively treated. One specimen, the proper placement of which is doubtful,

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is described under *Scorpaena albifimbria.* Also, no specimens of *Pontinus corallinus* Miranda Ribeiro are available for study, as noted under the account of that genus. Three species and subspecies not occurring in the western Atlantic, two European and one from the American Pacific coast, are here treated in order to compare them with their near western Atlantic relatives.

It is of interest and value to compare the results of this study with my recent (1951) revision of the western Atlantic tonguefishes, *Symphurus.* Of the 14 species of *Symphurus* distinguished, 6 proved to be new. On the other hand, 23 scorpaenid species are here distinguished from the same faunal region, and not a single new species has been found, while 17 names established in comparatively recent years are reduced to synonymy. The difference in the results obtained is readily explicable by the difference in the subject matter. The species of *Symphurus* are very similar in general appearance, and most species are hardly distinguishable on sight. It is only after an accurate determination of the numbers of fin rays and scales is made, aided by other characters of lesser importance, that the species become distinguishable properly. This is at least one of the reasons why relatively so many species remained undescribed. Scorpaenid species, on the other hand, are subject, to an extraordinary extent, to a wide range of intraspecific individual variability and growth changes. As a consequence, individual variants, or specimens representing different growth stages of the same species, have been erroneously described as distinct species. The difference in the taxonomic treatment hitherto afforded these two families furnishes an enlightening commentary on current taxonomic methods.

For an adequate account of western Atlantic scorpaenids, a study of the specimens in the National Museum is indispensable. The national collection includes the types of 26 valid or nominal species that have been described, 22 of which are holotypes, the other 4 cotypes or paratypes. What is just as important, in a number of species the specimens in the collection are of sufficient extent to serve as a basis for the determination, with a measure of satisfaction, of the intraspecific range of variability of important specific characters, or the determination of growth changes in such characters. I was fortunate in being able to study this valuable scorpaenid collection from the western Atlantic, and this paper is based largely on this collection. I also examined types and other specimens in the American Museum of Natural History, Bingham Oceanographic Collection, New York Zoological Society, Academy of Natural Sciences of Philadelphia, University of Michigan Museum of Zoology, and the Chicago Natural

History Museum. I am deeply grateful to the authorities of all these institutions for the privilege of studying their material.

The illustrations accompanying this paper were drawn by Mrs. Mildred H. Carrington.

The family Scorpaenidae has been considered hitherto a difficult group from a taxonomic viewpoint, and it is particularly so when current accounts are used for the purpose of identifying the species. By way of illustration of existing uncertainties and errors in the taxonomy of the species concerned, I found about half of the many lots of specimens in the National Museum were either misidentified or identified as to genus only, some of them bearing even an erroneous generic identification. The number of names proposed during the last 40 years, which it was found necessary to reduce to synonymy, as discussed above, is remarkable. However, after determining intraspecific variability and growth changes the difficulties largely disappear, and scorpaenid fishes are then not more difficult to distinguish than species in many another family. In some respects they are easier to distinguish, because the spinous armature of the head furnishes valuable generic and specific characters, as discussed below, that are not present in other families. Characters common to the genera and species here treated are as follows.

SYSTEMATIC DESCRIPTIONS

Family SCORPAENIDAE

Elongate, moderately deep to rather slender, moderately to well compressed. Snout short to rather long. Eye medium to large, smaller to larger than snout. Interorbital differing with the species from subequal to eye to one-third the eye. Upper jaw with a broad notch at the symphysis slightly to well developed, tip of lower jaw fitting into the notch; lower jaw with an external knob near its end, slightly to well developed; notch and knob hardly perceptible in individual variants of some species. Mouth of medium extent, moderately inclined, terminal, the jaws subequal, the lower very slightly projecting to very slightly included. Maxillary of moderate length, ending under anterior margin of pupil to under posterior margin of eye or a little behind. Teeth in jaws on vomer and palatines, except palatine teeth lacking in *Scorpaenodes;* small, subequal or inner teeth in jaws slightly enlarged in some species; those in jaws in narrow bands of medium width, those on vomer and palatines differing from one row to bands of medium width. Opercle with 2 spinous points, not extending beyond its margin; the 2 spines forming tips of divergent ridges in most species, the ridges faint or absent in some species. Head with spines occupying definite positions. (The spines and their nomenclature being of much taxonomic importance are treated separately below.) Upper outer corner of interopercle and lower outer corner of subopercle ending in an acute angle or rather sharp spinous point as an individual variation in some species. Cheek with a lengthwise bony stay extending from preorbital to preopercle forming a ridge externally, usually bearing spinous points (hereafter designated as the suborbital ridge). Gill opening wide, branchiostegal membranes forming a slight fold under eye. No gill slit on inner side of fourth arch or a small slit present. Pseudobranchiae well or moderately developed. Gill rakers in most species short, broad, comparatively few, those at both ends of arch very short, tubercle-like, the gill rakers grading very gradually into the tubercles or a rather indefinite line of demarcation between them, rather well delimitable in some species. Various appendages on head, body, and also upper part of eyeball, varying from rather long, stout tentacles on upper margin of orbit to short, broad tabs and slender filaments, their development varying widely and to a large extent dependent on individual variability; also governed by average species differences, only of limited value for the definitive distinction of the species. Lateral line normal except in *Setarches parmatus* (see account of this species). Scales ctenoid or cycloid, in 40-110 transverse rows; body scaled all over, including chest and fleshy pectoral base (more or less embedded in latter two situations in some species, sometimes not visible at the surface); head partly or almost wholly scaled; caudal and pectoral moderately scaled at their base; dorsal and anal moderately or slightly scaled at their base in some species; fins otherwise scaleless. Dorsal typically or predominantly with 12, 13, or 15 spines, depending on the genus, the number of variants from the predominating counts very few, except in *Sebastes;* with 7-15 soft rays; first three spines rapidly graduated, fourth spine usually longest in most species, slightly longer than third or fifth, sometimes third or fifth slightly longer than fourth as a slight average specific difference or as an individual variation (except in *Pontinus longispinis* and in the males of *Neomerinthe beanorum* the third spine notably prolonged beyond the others), thence decreasing in length to penultimate; last spine considerably or moderately longer than penultimate, emargination of fin between last two spines moderate or pronounced, depending on the species. Anal with 3 spines; normally with 5 rays, the number of variants from the normal very few, except with 7-10 rays in *Sebastes marinus;* first spine much shorter than second; third varying between moderately longer or shorter than second. Outer ventral angle under lower pectoral angle differing a little both ways, its end reaching anal origin or falling short of vent. Pectoral with 15-24 rays, the upper 4-10 rays, except uppermost 1-3, branched, the lower ones unbranched, more or less thickened and free at their tips, or all unbranched (in *Pontinus*); end of fin on a vertical differing from moderately in front of anal base to a little behind, its shape differing to some extent with the genus (see fig. 4). Caudal rounded or slightly emarginate.

SOME TAXONOMIC CHARACTERS, THEIR DEFINITION AND METHODS OF STUDY

Spines on head.—The distribution and development of the spines on the head constitute valuable specialized characters that aid in the distinction of the species and genera of this family. This is in addition to the taxonomic characters generally employed in ichthyology for the distinction of species and genera, such as the nature and extent of the dentition; counts of fin ray supports, gill rakers and scales; the shape and extent of the fins and parts of the head and body; proportional measurements; etc. As a consequence, scorpaenid genera and species are potentially distinguishable with greater ease and adequacy than those in some other families of fishes. One of the main reasons this has not proved to be so hitherto and the resultant unsatisfactory state of scorpaenid taxonomy at present is the general lack of a uniform nomenclature in designating the various spines, which often makes it virtually impossible to correlate accounts by different authors, or to understand adequately the precise structure of the species from the description given by any one author. To overcome this difficulty, the nomenclature of the spines as used in this paper is hereafter stated and the relative positions of the different spines are illustrated in figures 1 and 2, which represent *Scorpaena plumieri.* This species has been selected for illustration because it is a widespread species which is not uncommon, and it has the full complement of the important spines possessed by the species here treated, with the exception of the interorbital spines that, among these species, are present only in *Scorpaenodes.* In the species figured, a so-called spine is often not a spine in the true sense of the word—that is, it is not a slender bony structure with a sharp point. It is rather a blunt point at the summit of a flat, somewhat shelflike bony projection. However, the real spinelike projections and the broad, blunt projections are evidently homologous, and all are hereafter spoken of as spines. The nomenclature here used for the spines follows.

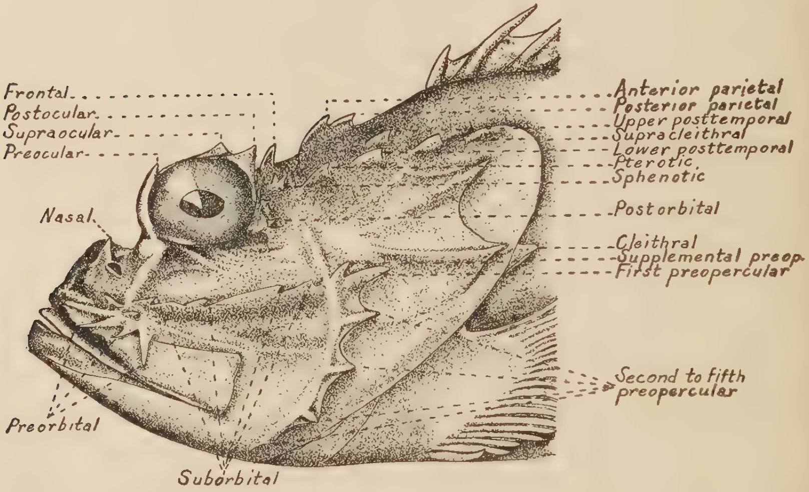
Frontal
Postocular
Supraocular
Preocular
Nasal
Preorbital
Suborbital
Anterior parietal
Posterior parietal
Upper posttemporal
Supracleithral
Lower posttemporal
Pterotic
Sphenotic
Postorbital
Cleithral
Supplemental preop.
First preopercular
Second to fifth preopercular

Fig. 1.—Side view of the head of *Scorpaena plumieri* showing the spines and their nomenclature as used in this paper. Semidiagrammatic. Drawn by Mildred H. Carrington.

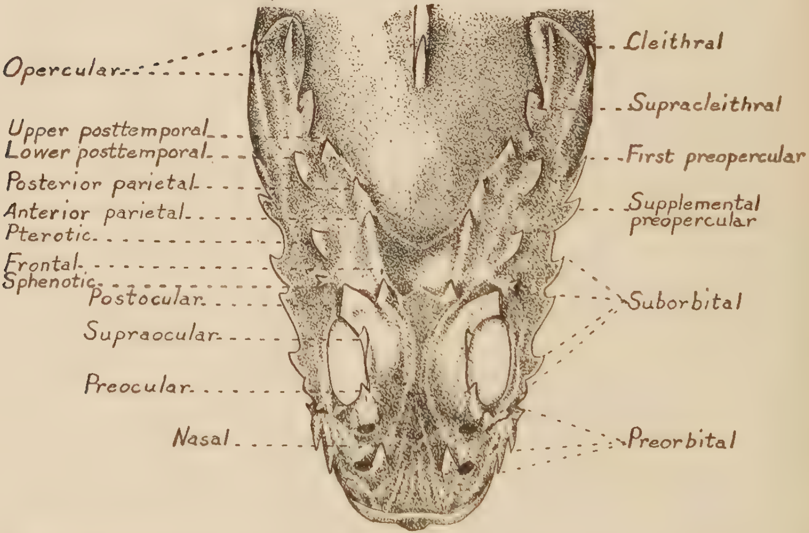
Opercular
Upper posttemporal
Lower posttemporal
Posterior parietal
Anterior parietal
Pterotic
Frontal
Sphenotic
Postocular
Supraocular
Preocular
Nasal
Cleithral
Supracleithral
First preopercular
Supplemental preopercular
Suborbital
Preorbital

Fig. 2.—Dorsal aspect of the head of *Scorpaena plumieri* shown in figure 1. Drawn by Mildred H. Carrington.

NASAL: A spine located dorsad of the nostrils, nearer to one or the other nostril or equally distant from the two. It is present in all the species here treated, but its extent of development differs with the species. The presence of this spine is not further mentioned under the accounts of the genera and species, except where its degree of development is unusual.

PREOCULAR, SUPRAOCULAR, POSTOCULAR: Three spines on the upper orbital rim, one approximately over the anterior margin of the pupil; the posterior two much closer to each other than to the anterior one, placed approximately over the posterior margin of the pupil. The preocular is present in all the species here treated; the supraocular and postocular are present in all except *Setarches parmatus*. Therefore, the presence of these spines is not especially mentioned under the accounts of the other genera and species.

INTERORBITAL: Two spinous points on interorbital space, each at the end of a ridge, one on each side of the midline. These spines are present only in *Scorpaenodes* and are not further mentioned under the accounts of the other genera and species.

PARIETAL, ANTERIOR AND POSTERIOR: The parietal ridge is placed a little to the side of the middorsal line, between the eye and the dorsal origin and a little nearer the eye. It is split into two parts, both ending in spines, except in *Sebastes marinus* and *Setarches parmatus* in which it is entire, ending in a single spinous point. The two spines are hereafter designated as the anterior and posterior parietal, the anterior one lacking in the two exceptional species mentioned.

FRONTAL: A spine placed at a short distance behind postocular; in front of and in a line with parietal ridge, or nearly in a line with postocular and somewhat laterad of parietal ridge. This spine is present in all species except *Setarches parmatus*, and disappears with growth in *Scorpaena grandicornis*.

SPHENOTIC: A comparatively small spine or spinule directly behind eye at a moderate distance below frontal. It is often bifid, or it consists of a group of spinules or asperities. It is subject to considerable intraspecific individual variation and is of only secondary importance in classification.

PTEROTIC: When present it is usually in the form of a ridge ending in a spinous point, placed at a moderate distance behind the sphenotic.

POSTTEMPORAL, UPPER AND LOWER: Two spinous points, one above the other, at a rather short distance in front of angle formed by the attachment of the opercle to the side. Often each forms the end point of a ridge. Both are subject to considerable intraspecific individual variability in some species.

SUPRACLEITHRAL: Placed at the upper angle of the gill opening. It is usually a blunt bony angle rather than a spine. In *Scorpaenodes* the exposed part of the supracleithrum is long, tapering, and ends in a sharp point.

In the species of *Scorpaena,* on the dorsal aspect of the head behind the eyes, the above spines in general are arranged in three somewhat irregular lengthwise rows; an inner row near the midback including the frontal and anterior and posterior parietal; an outer row approximately through the upper margin of the pupil consisting of the sphenotic, pterotic, and lower posttemporal; a row in between comprising the upper posttemporal and supracleithral. In *S. calcarata* the arrangement differs somewhat, and it is not altogether the same in other species of *Scorpaena.* In species of other genera the arrangement does not always quite follow the pattern outlined above.

POSTORBITAL: A spinule, entire or bifurcate or doubled, or a group of spinules or asperities, or one or more small tuberosities placed on a horizontal approximately through middle of eye and behind it. This is subject to a good deal of individual variability and is not of much importance in classification.

CLEITHRAL: A projection on the cleithrum in a position a little above the pectoral base, with a blunt apex or ending in a rather sharp spinous point. This projection is subject to change with growth, at least in some species. It is of moderate importance in distinguishing some of the species.

SUBORBITAL: The suborbital ridge, that is, the ridge on the "bony stay" on the cheek, has 0-7 spinous points, the number differing with the species, but also varying intraspecifically to a considerable extent. The ridge and its spines also change markedly with growth in some species. (See accounts of *Pontinus castor* and *Neomerinthe pollux.*)

PREORBITAL: The preorbital bone has a number of radiating ridges two or three of which end in free spinous points at its outer margin. Another free spinous point is sometimes present in a line with the suborbital row of spines and is hereafter included in the count of that row.

Two scales on the lateral line directly behind the supracleithral spine have well-developed ridges which often end in spinous points or nearly so. Homologically these are not spines and are not considered as such. The anterior one of the two scales forms the starting point of the scale count as recorded in this paper.

The terminology of the spines outlined above follows that of the bones of which they are a part, except the spines on the upper rim of the orbit, on the interorbital, and that behind the middle of the eye which it seems best to designate according to their position, namely, preocular, supraocular, postocular, interorbital, and postorbital. (For illustrations and descriptions of scorpaenid skulls, see Gregory 1933, pp. 241 and 323.) Previous attempts have been made by authors to introduce a uniform system of nomenclature for the spines, two of the later ones being by Schultz (1943, p. 168, fig. 14) and by Clemens and Wilby (1949, pp. 16-18, fig. 8). The nomenclature here adopted is in the main a combination of that used by previous authors with the introduction of some modifications in detail. It is hoped that the nomenclature here proposed will contribute toward the final adoption of a general uniform system of nomenclature to be used for the family as a whole.

Preopercular spines.—The spinous structure of the preopercular margin furnishes valuable taxonomic characters. The preopercle has a basic 5-spined pattern, and modifications within this basic pattern are of importance in distinguishing the genera and species. In *Sebastes* and *Helicolenus* the second spine is the longest, in *Setarches* the upper three spines are subequal or nearly so, while in the other five genera the first spine is the longest. In *Neomerinthe* and *Pontinus* the second spine is present or absent depending on the species and on intraspecific individual variability in some species. The fourth and fifth spines are sharply marked in some species and much reduced and variable or virtually absent in others. The presence or absence of a supplementary spine or spur attached to the first spine is sometimes a fairly good specific character. It is also important to bear in mind that the supplementary spine is homologically not the first spine as discussed below under the account of *Scorpaena plumieri mystes*. Specific and generic differences in the outline of the posterior margin of the preopercle are shown in figure 3.

In two species at least, *Pontinus longispinis* and *P. rathbuni* (see accounts of these), the spines on the preopercle of juveniles, about 20-30 mm. specimens examined, differ markedly from that in the larger specimens, the upper three spines in general being of approximately the same size, similar to that of grown specimens of *Setarches parmatus*. This growth change is important, as the relative size of the spines is here used as a major character in the division of the genera.

Dorsal fin.—The penultimate dorsal spine is shorter than the last and the dorsal fin is emarginate between the spinous and soft parts or rather between the last two spines. The extent of emargination differs in degree among the different species, with all gradations between the extremes. Therefore, for descriptive purposes and in the formulas at the head of the accounts of the different species, the dorsal is treated as though it formed a single fin, although in the more extreme species it might as well be treated as consisting of two fins.

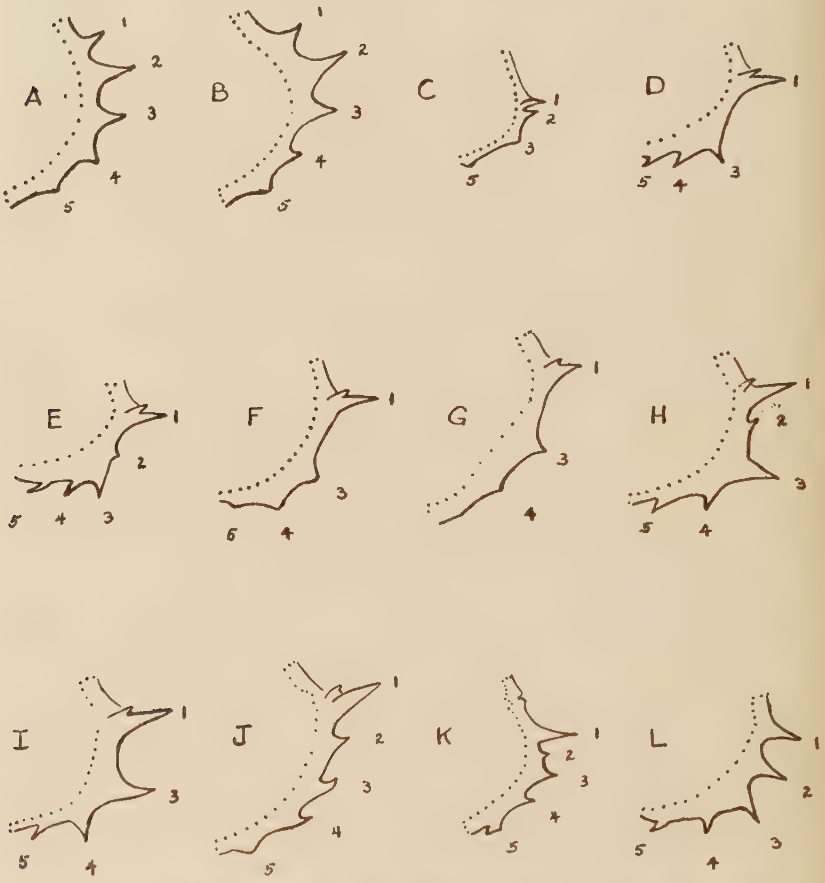

Fig. 3.—Preopercular outline of scorpaenid species: A, *Sebastes marinus.* B, *Helicolenus maderensis.* C, *Scorpaenodes caribbaeus.* D, *Neomerinthe beanorum,* usual condition, second spine absent. E, *Neomerinthe beanorum,* variant showing a very moderate second spine. F, *Neomerinthe pollux.* G, *Pontinus castor.* H, *Pontinus longispinis,* usual condition, a small second spine present. I, *Pontinus longispinis,* a variant lacking second spine. J, *Trachyscorpia cristulata.* K, *Scorpaena calcarata,* second spine usually present and small as figured, sometimes absent. L, *Setarches parmatus.* Drawn by Mildred H. Carrington.

The number of spines constitutes a generic character of some value, typically being 12 or 13, depending on the genus, with comparatively few variants from the typical (table 1), except in *Sebastes* in which the modal number is 15 and the variants from that count are com-

Table 1.—*Frequency distribution of the number of dorsal spines and dorsal and anal rays in western Atlantic scorpaenias and three others*

Species and subspecies	Dorsal spines					Dorsal rays									Anal rays						
	11	12	13	14	15	7	8	9	10	11	12	13	14	15	4	5	6	7	8	9	10
Sebastes marinus	..	..	..	6	62	..	..	..	..	..	..	27	30	8	..	..	..	46	17	4	1
Helicolenus dactylopterus	..	7	..	..	..	..	..	..	..	..	7	..	..	..	..	7	..	..	..	..	..
“ *maderensis*	2	174	4	..	..	..	..	..	1	28	144	6	..	..	2	179	..	..	..	..	..
“ *lahillei*	..	8	1	..	..	..	..	..	..	1	7	1	..	..	..	9	..	..	..	..	..
Scorpaenodes caribbaeus	..	..	3	..	..	..	..	2	..	..	..	..	..	..	..	2	..	..	..	..	..
“ *tridecimspinosus*	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..
“ *floridae*	..	..	2	..	..	..	1	1	..	..	..	..	..	..	..	2	..	..	..	..	..
Pontinus macrolepis	..	4	..	..	..	..	..	4	..	..	..	..	..	..	..	4	..	..	..	..	..
“ *longispinis*	..	79	..	..	..	..	..	77	2	..	..	..	..	..	..	79	..	..	..	..	..
“ *rathbuni*	1	27	..	..	..	..	..	26	2	..	..	..	..	..	..	28	..	..	..	..	..
“ *castor*	..	4	..	..	..	..	..	..	4	..	..	..	..	..	..	4	..	..	..	..	..
Neomerinthe pollux	..	14	..	..	..	..	..	..	16	..	..	..	..	..	..	16	..	..	..	..	..
“ *beanorum*	..	6	..	..	..	..	..	6	..	..	..	..	..	..	..	6	..	..	..	..	..
Trachyscorpia echinata	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..
“ *cristulata*	..	13	..	..	..	..	1	12	..	..	..	..	..	..	..	13	..	..	..	..	..
Scorpaena inermis	..	18	..	..	..	3	14	1	..	..	..	..	..	..	..	18	..	..	..	..	..
“ *calcarata*	3	204	1	..	..	..	23	181	3	..	..	..	..	..	3	200	5	..	..	..	..
“ *agassizi*	..	103	1	..	..	..	4	100	..	..	..	..	..	..	2	104	..	..	..	..	..
“ *brasiliensis*	..	125	2	..	..	1	3	124	..	..	..	..	..	..	1	125	2	..	..	..	..
“ *grandicornis*	..	65	2	..	..	..	2	64	1	..	..	..	..	..	3	64	..	..	..	..	..
“ *bergi*	1	37	..	..	..	..	1	37	..	..	..	..	..	..	..	38	..	..	..	..	..
“ *albifimbria*	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..
“ *dispar*	1	15	..	..	..	..	2	14	..	..	..	..	..	..	..	16	..	..	..	..	..
“ *plumieri*	..	67	..	..	..	..	2	65	..	..	..	..	..	..	..	67	2	..	..	..	..
“ *mystes*	..	12	..	..	..	..	..	12	..	..	..	..	..	..	1	11	..	..	..	..	..
“ *microlepis*	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..
Setarches parmatus	..	40	..	..	..	..	..	11	30	..	..	..	..	..	1	41	..	..	..	..	..

paratively more numerous. The number of soft rays in most species is also remarkably constant as compared with species in other families; and it is of some value, in a more limited way, as a specific and generic character. The last two rays, which are closely approximated at their bases and appear to be the two main branches of a ray that is split to its base, have been counted as one ray in both the dorsal and anal.

Anal fin.—The number of anal spines, 3, is virtually constant. In routine counts made during this investigation on 1,139 specimens, only 2 differed from the normal count of 3. In one specimen each of *Pontinus longispinis* and *P. rathbuni,* out of 79 and 28 examined of those two species, respectively, the first short anal spine is missing. The number of rays is nearly always 5, the number of variants being comparatively few (table 1), except in *Sebastes marinus* which has 7 to 10 rays. The relative length of the second and third spine is of moderate importance as a specific character.

Development of third anal spine.—An important point that has a bearing on the classification of fishes in general was observed on two specimens, 24-25 mm., of *Pontinus longispinis* (155999-155300).[1] The third anal fin support is flexible and partly jointed for some distance at its distal end. In the next size examined of the same species, 30 mm., the third anal spine is as in the adult. This developmental phenomenon was heretofore well known in the species of *Mugil.* I have also observed it in the family Haemulonidae, in the species of *Orthopristes, Haemulon,* and *Bathystoma.* This noteworthy development, therefore, seems to be widespread in fishes. As the number of anal spines, 1, 2, or 3, is sometimes used as a family character, it is of interest to know that it depends on ontogenetic development in families of fishes which are otherwise widely divergent in the scheme of classification.

In specimens examined of *Pontinus rathbuni, Scorpaena calcarata,* and *S. agassizi,* 18-22 mm., the third anal spine is as in the adult. *P. rathbuni* is a smaller species than *longispinis* and this developmental change probably occurs at a smaller size. In the species of *Scorpaena,* on the other hand, it is possible that the third anal spine is as in the adult to begin with.

Pectoral fin.—The pectoral shape differs with the genus to a certain extent, although this character is not altogether stable because of the irregularity in the relative contraction or expansion of the interradial membrane in preserved specimens, which influences the shape of the fin. Nevertheless, allowing for this difficulty of the subject matter and for a considerable latitude in accounting for specific differences and intraspecific variability, this character still has some generic value. The pectorals of four genera are illustrated in figure 4.

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[1] Numbers of specimens examined are U. S. National Museum catalog numbers unless otherwise indicated.

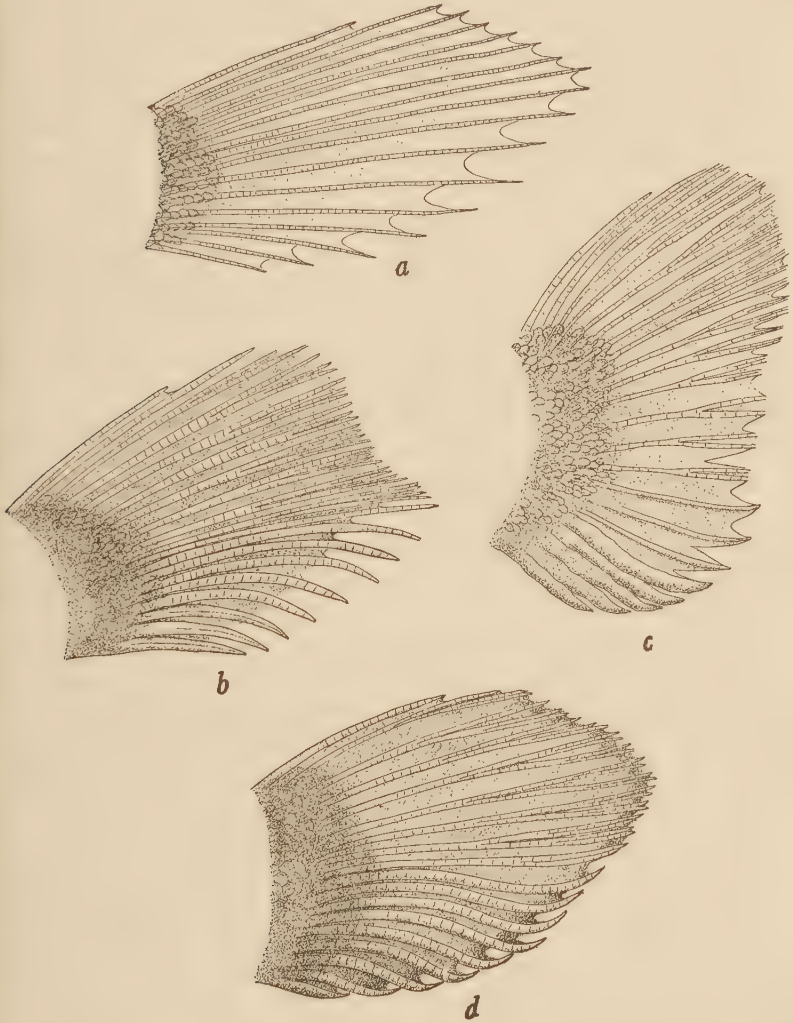

Fig. 4.—Pectoral fins of four scorpaenid species. The shape of the pectoral fin is generic to some extent. *a, Pontinus longispinis; b, Helicolenus maderensis; c, Trachyscorpia cristulata; d, Scorpaena grandicornis.* Drawn by Mildred H. Carrington.

One genus, *Pontinus,* is separable from the others here treated by having all the pectoral rays unbranched. The number of pectoral rays is, on the whole, of considerable importance as a specific character (table 2), although related species often overlap in this count.

Scales.—The structure of the scales, cycloid or ctenoid, appears to be of considerable value as a generic character and it is here so used. This character was inadequately treated heretofore. Jordan and Evermann (1898, p. 1759), in their key to the genera, use the structure of the scales on top of the head, ctenoid or cycloid, as a character in separating *Helicolenus* from *Scorpaena*. This character as used by the authors cited is unsatisfactory for this purpose and was the cause of some misapprehension by later authors in the treatment of the species. By the use of the structure of the scales on the body as a generic character the species fall into what seem to be natural groups. In the species with cycloid scales, which are here placed in the genus *Scorpaena,* the scales on the dorsal aspect extend only to opposite the parietal ridge; the occiput, interorbital, and snout being scaleless. The other genera here treated, excepting the highly specialized *Setarches,* have ctenoid scales on the body and the ctenoid scalation on the dorsal aspect extends to opposite the posterior part of the eye. On the greater part of the top of the head, on the interorbital and snout, the scalation in the species of these genera differs in its extent and structure with the species, from being scaled with weakly ctenoid or cycloid scales to being nearly scaleless.

The scale counts here given refer to the number of vertical rows above the lateral line, beginning with the row which is partly or wholly just behind the supracleithral spine, and ending at the caudal base. The two scales in the lateral line directly behind the supracleithral spine are more or less ridged and sometimes rather spinous. The rows standing over these two modified scales are included in the count. Usually the rows deviate somewhat from the vertical, running slightly forward or backward, often in different parts of the same specimen. Very often the scales are somewhat irregularly arranged instead of being alined in clear-cut rows, and in such cases the number of vertical rows counted is a rather rough approximation instead of being precise. However, by using throughout the same method of counting, the figures obtained yield fairly regular frequency distributions, and the scale count is useful as a specific character. The number of modified scales in the lateral line is much less than the number of vertical rows above it, does not differ much as between related species, and is not of much importance as a specific character.

Gill rakers.—In the Scorpaenidae the gill rakers on the outer gill arch usually gradually decrease in size from the angle forward or upward, and in most species it is not possible to draw a consistent line between the gill rakers and the so-called rudiments or tubercle-like outgrowths. On the other hand, the tubercles are generally well defined, except that in some species, toward the anterior part of the lower limb, they are not sharply marked in individual variants. On the whole, the combined number of gill rakers and tubercles is determinable with a fair or high degree of precision, except for the relatively few individual variants noted. Therefore, the combined number of gill rakers and tubercles is given under each species in the formula and the text and also in tables 2-4, as this count yields the best results in adequately distinguishing the species and genera of this family. *Setarches parmatus* forms an exception in regard to the relative development of gill rakers and tubercles and these structures are discussed separately under the account of that species.

TABLE 2.—*Frequency distribution of the number of pectoral rays in western Atlantic scorpaenids and three others*

Species and subspecies	Distribution									
	15	16	17	18	19	20	21	22	23	24
Sebastes marinus	..	..	..	13	51	4	..	..	..	..
Helicolenus dactylopterus	..	..	..	..	6	1	..	..	..	..
“ *maderensis*	..	..	2	29	142	8	..	..	..	..
“ *lahillei*	..	..	..	1	8	..	..	..	..	..
Scorpaenodes caribbaeus	..	..	..	2	4	..	..	..	..	..
“ *tridecimspinosus*	..	..	2	..	..	..	..	..	..	..
“ *floridae*	..	..	4	..	..	..	..	..	..	..
Pontinus macrolepis	1	3	..	..	..	..	..	..	..	..
“ *longispinis*	..	1	73	2	..	..	..	..	..	..
“ *rathbuni*	..	..	21	1	..	..	..	..	..	..
“ *castor*	..	..	4	..	..	..	..	..	..	..
Neomerinthe pollux	..	..	16	..	..	..	..	..	..	..
“ *beanorum*	..	..	6	..	..	..	..	..	..	..
Trachyscorpia echinata	..	..	..	..	..	1	..	..	..	..
“ *cristulata*	..	..	..	..	..	..	..	1	9	3
Scorpaena inermis	..	..	..	..	4	13	1	..	..	..
“ *calcarata*	..	..	..	1	23	152	29	..	..	..
“ *agassizi*	..	..	..	..	10	84	10	..	..	..
“ *brasiliensis*	..	..	1	13	95	19	..	..	..	..
“ *grandicornis*	..	..	4	56	7	..	..	..	..	..
“ *bergi*	..	5	32	1	..	..	..	..	..	..
“ *albifimbria*	..	..	..	..	1	..	..	..	..	..
“ *dispar*	..	..	2	9	4	..	..	..	..	..
“ *plumieri*	..	..	..	2	38	26	3	..	..	..
“ *mystes*	..	..	..	..	..	12	..	..	..	..
“ *microlepis*	..	1	..	1	..	..	..	..	..	..
Setarches parmatus	..	..	..	..	..	..	..	3	27	12

In counting the gill rakers the one at the angle is included in the count of the lower limb.

Gill slit behind fourth arch.—The presence or absence of a small slit behind the fourth gill arch is of some generic or specific value. This character does not constitute an absolute difference. In *Pontinus* the slit is either altogether open or it is bridged over at its outer side with a thin, easily torn membrane. In *Scorpaenodes* its presence appears to differ with the species, judged by the very few specimens examined. Moreover, this character is not easy to apply in practice. In examination it often requires some pressure to move the fourth arch sufficiently to expose and examine its line of attachment, and an artificial slit might be made in doing so.

TABLE 3.—*Frequency distribution of the combined number of gill rakers and tubercles on the upper limb of western Atlantic scorpaenids and three others*

	Distribution						
Species and subspecies	3	4	5	6	7	8	9
Helicolenus dactylopterus	..	..	..	..	6	1	..
“ *maderensis*	..	..	..	..	58	60	5
“ *lahillei*	..	..	..	..	2	7	..
Scorpaenodes caribbaeus	..	..	..	1	3	2	..
“ *tridecimspinosus*	..	..	2	..	..	..	..
“ *floridae*	..	1	3	..	..	..	..
Pontinus macrolepis	..	..	..	..	3	1	..
“ *longispinis*	..	..	..	25	20	..	..
“ *rathbuni*	..	..	1	11	8	1	..
“ *castor*	..	..	..	..	3	1	..
Neomerinthe pollux	..	..	..	15	1	..	..
“ *beanorum*	..	..	..	6	..	..	..
Trachyscorpia echinata	..	..	1	..	..	..	..
“ *cristulata*	..	..	..	13	..	..	..
Scorpaena inermis	1	13	4	..	..	..	..
“ *calcarata*	1	74	65	..	..	..	..
“ *agassizi*	..	6	62	5	..	..	..
“ *grandicornis*	..	6	36	24	1	..	..
“ *brasiliensis*	..	116	12	..	..	..	..
“ *bergi*	6	32	..	..	..	..	..
“ *albifimbria*	..	..	1	..	..	..	..
“ *dispar*	..	..	15	..	..	..	..
“ *plumieri*	..	5	59	2	..	..	..
“ *mystes*	..	1	10	..	..	..	..
“ *microlepis*	..	..	1	..	..	..	..
Setarches parmatus	..	..	..	6	36	..	..

Appendages of skin.—The species of this family have soft appendages of skin in various stages of development that may be designated as tentacles, filaments, or tabs, depending on their relative length or thickness. They are often situated at the base of the various spines on the head, along the course of the lateral line, on the upper part of the eyeball, or irregularly scattered on the head and body. These appendages have been used often as taxonomic characters in distinguishing species or even genera and are sometimes used in keys. However, their use as distinguishing characters has been exaggerated hitherto with misleading results. They are generally so variable intraspecifically that in only a few instances can they be used constructively in distinguishing related congeneric species. On the whole, it would serve best the advancement of scorpaenid taxonomy not to put undue emphasis on these structures as taxonomic characters.

4.—*Frequency distribution of the combined number of gill rakers and tubercles on the lower limb of western Atlantic scorpaenids and three others*

	Distribution													
ecies and subspecies	6	7	8	9	10	11	12	13	14	15	16	17	18	19
olenus dactylopterus	..	..	..	..	..	..	..	..	..	..	1	3	3	..
" *maderensis*	..	..	..	..	..	..	..	..	..	..	7	66	50	..
" *lahillei*	..	..	..	..	..	..	..	..	..	..	..	2	6	1
aenodes caribbaeus	..	..	..	..	3	..	2	1	..	..	..	..	..	..
" *tridecimspinosus*	..	..	..	..	2	..	..	..	..	..	..	..	..	..
" *floridae*	..	..	..	..	..	4	..	..	..	..	..	..	..	..
nus macrolepis	..	..	..	..	..	..	1	3	..	..	..	..	..	..
longispinis	..	..	..	..	..	..	8	28	8	1	..	..	..	..
rathbuni	..	..	..	..	..	..	12	8	1	..	..	..	..	..
castor	..	..	..	..	..	..	..	..	3	1	..	..	..	..
erinthe pollux	..	..	..	1	2	4	9	..	..	..	..	..	..	..
" *beanorum*	..	..	..	4	2	..	..	..	..	..	..	..	..	..
hyscorpia echinata	..	..	..	..	..	..	..	1	..	..	..	..	..	..
" *cristulata*	..	..	..	..	..	..	..	13	..	..	..	..	..	..
baena inermis	1	12	5	..	..	..	..	..	..	..	..	..	..	..
" *calcarata*	..	2	20	78	38	2	..	..	..	..	..	..	..	..
" *agassizi*	..	..	6	23	39	5	..	..	..	..	..	..	..	..
" *brasiliensis*	..	..	7	98	23	..	..	..	..	..	..	..	..	..
" *grandicornis*	..	1	5	43	18	..	..	..	..	..	..	..	..	..
" *bergi*	..	2	7	25	4	..	..	..	..	..	..	..	.	..
" *albifimbria*	..	..	..	..	1	..	..	..	..	..	..	..	..	..
" *dispar*	..	..	..	..	7	7	1	..	..	..	..	..	..	..
" *plumieri*	..	..	3	14	29	17	3	..	..	..	..	..	..	..
" *mystes*	..	..	..	1	6	4	..	..	..	..	..	..	..	..
" *microlepis*	..	..	..	..	..	1	..	..	..	..	..	..	..	..
ches parmatus	..	..	..	..	3	8	6	13	7	5	..	..	..	..

The following examples might be briefly cited in regard to the use of these structures as taxonomic characters. The tentacle between the

TABLE 5.—*Frequency distribution of the combined total number of gill rakers and tubercles of western Atlantic scorpaenids and three others*

Species and subspecies	Distribution																	
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Helicolenus dactylopterus	..	..	..	..	..	..	..	..	..	..	..	..	..	1	3	2	1	..
“ *maderensis*	..	..	..	..	..	..	..	..	..	..	..	..	..	6	38	43	32	4
“ *lahillei*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	4	1
Scorpaenodes caribbaeus	..	..	..	..	..	..	1	2	..	..	3	..	..	..	..	..	..	..
“ *tridecimspinosus*	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..
“ *floridae*	..	..	..	..	..	1	3	..	..	..	..	..	..	..	..	..	..	..
Pontinus macrolepis	..	..	..	..	..	..	..	..	..	1	2	1	..	..	..	..	..	..
“ *longispinis*	..	..	..	..	..	..	..	..	5	20	13	7	..	..	..	..	..	..
“ *rathbuni*	..	..	..	..	..	..	..	..	8	5	7	..	..	..	..	..	..	..
“ *castor*	..	..	.	..	..	..	..	..	..	..	..	2	2	..	..	..	..	..
Neomerinthe pollux	..	..	..	..	..	1	2	4	8	1	..	..	..	..	..	..	..	..
“ *beanorum*	..	..	..	..	..	4	2	..	..	..	..	..	..	..	..	..	..	..
Trachyscorpia echinata	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..
“ *cristulata*	..	..	..	..	..	..	..	..	..	13	..	..	..	..	..	..	..	..
Scorpaena inermis	2	8	7	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *calcarata*	..	2	16	48	47	26	1	..	..	..	..	..	..	..	..	..	..	..
“ *agassizi*	..	..	1	8	20	38	4	2	..	..	..	..	..	..	..	..	..	..
“ *brasiliensis*	..	..	6	90	30	2	..	..	..	..	..	..	..	..	..	..	..	..
“ *grandicornis*	..	..	2	7	24	26	8	..	..	..	..	..	..	..	..	..	..	..
“ *bergi*	1	2	10	21	4	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *albifimbria*	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..
“ *dispar*	..	..	..	..	..	7	7	1	..	..	..	..	..	..	..	..	..	..
“ *plumieri*	..	..	1	3	14	29	15	4	..	..	..	..	..	..	..	..	..	..
“ *mystes*	..	..	..	..	2	5	4	..	..	..	..	..	..	..	..	..	..	..
“ *microlepis*	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
Setarches parmatus	..	..	..	..	..	..	..	5	7	6	13	7	4	..	..	..	..	..

TABLE 6.—*Frequency distribution of the number of scales in western Atlantic scorpaenids and two others*

Species and subspecies	Distribution 40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
Scorpaenodes caribbaeus	..	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *tridecimspinosus*	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *floridae*	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pontinus macrolepis	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *longispinis*	..	..	..	..	..	..	..	1	3	4	1	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *rathbuni*	..	..	..	2	..	3	4	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *castor*	..	..	..	..	..	..	..	..	..	..	1	..	..	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Neomerinthe pollux	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	3	3	3	..	2	1
“ *beanorum*	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Trachyscorpia echinata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
“ *cristulata*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	2	1	..	..	..	..	1	1	..
Scorpaena inermis	..	..	..	..	3	2	3	3	4	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *calcarata*	..	2	3	13	18	29	12	9	3	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *agassizi*	..	..	..	1	4	2	6	12	14	12	6	2	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *brasiliensis*	..	..	..	..	..	..	..	..	..	..	2	8	13	14	18	14	13	10	6	5	2	2	1	..	..	..	..	..	..
“ *grandicornis*	..	..	..	..	10	17	21	13	4	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *bergi*	..	..	4	8	7	8	2	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *albifimbria*	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *dispar*	..	..	1	2	2	3	3	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *plumieri*	..	..	2	6	10	14	19	11	3	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
“ *mystes*	..	..	..	..	1	7	1	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

supraocular and postocular spines is on the average better developed in *Scorpaena grandicornis* than in *S. plumieri;* but in frequent individual variants of *plumieri* it is nearly as well developed as in most specimens of *grandicornis,* while in other variants it is hardly developed. The same situation is also found in comparing other pairs of species. On the other hand, the relative development of the tentacles at the supraocular spine is of some value in separating *grandicornis* from *bergi* and *albifimbria* and it is so used in the key here given, as an addition to other characters.

Measurements.—Proportional measurements given in the body of the report, the key, and the tables, are expressed as a percentage of the standard length. The methods used in obtaining some of the measurements here given are as follows.

In some thick-skinned species it is difficult to determine externally the point of articulation of the middle pectoral rays, and the precise length of such rays could not be well determined. Therefore, measurements of the pectoral given hereafter were made from the point of articulation of the upper rays to the posterior apical point of the fin, that is, to the end of the ray extending farthest backward. The given measurement deviates somewhat from that of the longest ray.

The eye measurement here given refers to the greatest horizontal diameter of the ridge surrounding the eye. This measurement is most nearly susceptible of approaching accuracy. The size of the eyeball is subject to a great deal of individual variability in these species. In preserved specimens of the same species the eyeball fills the orbit or even bulges out of its limits, or it is variably shrunken within the orbit. These individual differences are most probably caused partly by some of the specimens having been brought up from rather deep water, and partly by preservation. At any rate, the size of the eyeball is not accurately determinable, and the term "eye" as used in this paper is synonymous with orbit.

The head was measured from its anterior margin, at the side of the notch when the latter is well developed, to its posteriormost point on its flexible marginal part. The depth was measured at the ventral base.

KEY TO THE GENERA AND SPECIES

1a. Lateral line normal, consisting of a series of modified channeled scales. Supraocular and postocular spines present. Spinous and soft part of dorsal more or less connected. Scales ctenoid, when cycloid (in *Scorpaena*) not more than 76.

2a. Second preopercular spine longest, the first more or less shorter. (The relative size of the preopercular spines is different in juveniles, of some species at least; see above.)
  3a. Dorsal spines usually 15, sometimes 14. Anal rays 7-10. Scales 87-110; accessory scales profuse except in small specimens (only species having accessory scales). Parietal ridge typically entire. Gill rakers 32-38 altogether. Pectoral rounded posteriorly, roughly wedge-shaped. *Sebastes marinus* (p. 26)
  3b. Dorsal spines normally 12, infrequently 11 or 13. Anal rays normally 5, rarely 4. Scales 60-79, without accessory scales. Parietal ridge divided into two parts. Total number of gill rakers 23-27. Pectoral broad, distal edge of its upper half emarginate; the lower rays thick, well separated distally (fig. 4b) .... *Helicolenus* (p. 30)
    4a. Suborbital ridge usually without a spine. Scales 66-73. Maxillary 21.5-22.5. Interorbital 2.9-3.2 times in eye (for size of specimens measured see under subspecies). Eastern Atlantic and Mediterranean. *Helicolenus dactylopterus dactylopterus* (p. 32)
    4b. Suborbital ridge usually with a spine.
      5a. Scales 60-71. Maxillary 20.0-22.5. Interorbital 2.1-3.4 times in eye. East coast of the United States. *Helicolenus dactylopterus maderensis* (p. 33)
      5b. Scales 68-79. Maxillary 18.5-20.5. Interorbital 1.9-2.7 times in eye. Atlantic coast of South America. *Helicolenus dactylopterus lahillei* (p. 36)

2b. First preopercular spine longest.
  6a. Dorsal spines normally 13. Palatine teeth absent. Interorbital spinous points present or obsolescent. Scales ctenoid, 40-42. (Only genus lacking palatine teeth, having spinous points on interorbital, and normally having 13 dorsal spines) .... *Scorpaenodes* (p. 37)
    7a. Suborbital ridge with 4-5 spinous points and 2 points in a line below main row. Gill rakers and tubercles on upper limb 6-8 in combined number. Pectoral rays 18-19. Interorbital ridges and spines well developed. Upper posttemporal spine small. Interorbital and snout rather well scaled........ *Scorpaenodes caribbaeus* (p. 38)
    7b. Suborbital ridge with 1-3 spinous points and no secondary row of spines below main row. Gill rakers and tubercles on upper limb 4-5. Pectoral rays 17. Interorbital ridges and spinous points moderate or obsolescent. Upper posttemporal absent. Interorbital and snout very sparsely scaled.
      8a. Suborbital ridge with 3 spinous points. *Scorpaenodes tridecimspinosus* (p. 40)
      8b. Suborbital ridge with 1 spinous point, at its end. *Scorpaenodes floridae* (p. 41)

6b. Dorsal spines normally 12. Palatine teeth present. No spinous spoints on interorbital.

9a. Scales ctenoid; occiput scaled. Occipital pit absent.

10a. Pectoral not broad, irregularly wedge-shaped; with 15-18 rays. A small slit behind fourth gill arch, sometimes bridged over by a thin membrane in individual variants of *Pontinus*.

11a. All pectoral rays unbranched (only genus having all such rays in pectoral). Total number of gill rakers and tubercles 18-22................*Pontinus* (p. 42)

12a. Snout short or moderate 12.6-14.4; eye 1.3 times in snout as a maximum, differing to a little larger than snout. Second preopercular spine normally present, except in some individual variants of *longispinis*. Dorsal rays usually 9, rather infrequently 10.

13a. Pectoral rays 15-16. Spines on suborbital ridge 3. Eye 12.9-15.4; interorbital 3.1-3.6 times in eye. Scales 45..........*Pontinus macrolepis* (p. 44)

13b. Pectoral rays usually 17, infrequently 18, rarely 16. Spines on suborbital ridge usually 4, occasionally 3. Eye 11.0-13.6; interorbital 2.3-3.2 times in eye.

14a. Third dorsal spine notably prolonged, except in specimens less than 115 mm. Scales 47-51. Depth 28-34 in specimens 51-174 mm. First preorbital spine usually directed downward or slightly forward. Tentacle at supraocular spine short and slender or absent. Typically spotted.
Pontinus longispinis (p. 45)

14b. Third dorsal spine not notably prolonged. Scales 43-48. Depth 33-39 in specimens 55-145 mm. First preorbital spine usually directed sharply backward. Tentacle at supraocular spine thick, broad, and rather long. Typically shaded or light-colored, spots usually absent; sometimes a few small spots; pectoral in small specimens with an elongate dusky smudge.
Pontinus rathbuni (p. 47)

12b. Snout notably long, 16-16.5; eye 1.4-1.6 times in snout. Second preopercular spine absent. Dorsal rays 10. Pectoral rays 17. Spines on suborbital ridge 3, except in large fish. Scales 50-54..........................*Pontinus castor* (p. 49)

11b. Pectoral having 1 or 2 uppermost rays unbranched, next 5-8 rays branched, lower 7-10 rays unbranched; total number of rays 17. Total number of gill rakers and tubercles 15-19. Second preopercular spine usually absent in the larger specimens, sometimes present in *beanorum*. Suborbital ridge with 3-4 spines..........*Neomerinthe* (p. 51)

15a. Scales 62-68. Dorsal rays 10. Upper posttemporal spine absent. Fourth preopercular spine obtuse, not antrorse; fifth poorly developed or obsolescent..........*Neomerinthe pollux* (p. 53)

15b. Scales 41-46. Dorsal rays 9. Upper posttemporal spine present. Fourth and fifth preopercular spines sharply pointed, antrorse. *Neomerinthe beanorum* (p. 56)

10b. Pectoral broad, not wedge-shaped, the longest rays a little below upper margin, its posterior edge slightly emarginate (fig. 4c), with 20-24 rays. No slit behind fourth gill arch............*Trachyscorpia* (p. 57)

16a. Head 43.5 (in one specimen 433 mm.). Pectoral rays 20. Body and head spotted. Eastern Atlantic......................*Trachyscorpia echinata* (p. 59)

16b. Head 47.5-48.0 (in 2 specimens 319-400 mm.; for measurements of other specimens see text). Pectoral rays 22-24. Without spots. Western Atlantic.....................*Trachyscorpia cristulata* (p. 61)

9b. Scales cycloid, 41-76; occiput not scaled. Occipital pit present, except in *inermis* and *calcarata* (the only genus containing species with a pit).........*Scorpaena* (p. 63)

17a. Preorbital spinous points 2.

18a. Occiput somewhat broadly depressed, without a definite pit. First preopercular spine without a supplemental spine.

19a. Inverted, mushroom-shaped, whitish figures extending downward from base of ocular tentacles at lengthwise boundary between upper opaque and lower transparent parts of cornea (these figures sometimes absent in smaller specimens; see account of species). First preopercular spine extending about half the distance or less from its base to opercular margin. Dorsal rays modally 8, varying 7-9. Combined number of gill rakers and tubercles on lower limb modally 7, varying 6-8. Interorbital 3.6-4.3 (in 5 specimens 71-89 mm.; for other sizes see species account). Without a definite spot behind head; caudal with 2 cross bands. *Scorpaena inermis* (p. 65)

19b. Short, oblong, whitish areas extending downward on transparent part of cornea sometimes present, more often absent. First preopercular spine usually extending for more than half the distance from its base to opercular margin. Dorsal rays modally 9, varying 8-10. Combined number of gill rakers and tubercles on lower limb modally 9, varying 7-11. Interorbital 4.6-6.5 (in 5 specimens 65-75 mm.). Usually with a dark spot a little behind head, sometimes faint or imperceptible; caudal usually without cross bands, sometimes a faint trace of such bands...........*Scorpaena calcarata* (p. 68)

18b. Occiput with a well-developed pit (rather shallow in *Microlepis*), except in young specimens. First preopercular spine with a supplemental spine or spur (often very small and infrequently virtually absent in *brasiliensis*).

20a. Eye notably large, snout 1.4-1.6 times in eye (1.5-2.2 in small fish). Pectoral long, 44.0-48.5 in the larger specimens, reaching to over end of anal or nearly so (34.5-35.0 in two specimens 31-36 mm.). In the larger specimens chest notably wrinkled in a cerebriform manner and scales on chest very deeply embedded, appearing scaleless at the surface. Posterior preorbital spine notably well developed. Scales 43-53.............*Scorpaena agassizi* (p. 71)

20b. Eye moderately large, snout 0.9-1.3 in eye. Pectoral 29.5-37.0 in the larger specimens, reaching to over base of third anal ray as a maximum (28-34 in small fish). Chest with an even surface and normally scaled. Posterior preorbital spine moderate or small.

21a. Scales 50-62. With a characteristic and rather unique color pattern, region at inner pectoral angle with small dark spots against a lighter background and side usually with 2, often 3 or 4, dark blotches, color pattern sometimes obscure. Upper posttemporal spine often absent..............*Scorpaena brasiliensis* (p. 74)

21b. Scales 42-49.

22a. Frontal spine absent in large specimens, notably small in the smaller specimens. Region at inner pectoral angle with light, small spots against a darker background. Tentacle at supraocular spine notably large.................*Scorpaena grandicornis* (p. 77)

22b. Frontal spine well developed. Without light spots at pectoral axil. Tentacle at supraocular spine small to well developed, sometimes large in individual variants of *bergi*. Small species.

23a. Depth 35.5-41.5 (in 37 specimens 33-92 mm.). Combined number of gill rakers and tubercles on upper limb usually 4, often 3. Body with light and dark shades; spinous dorsal with a blotch, better marked in faded specimens. Pectoral rays modally 17, often 16, infrequently 18.......... *Scorpaena bergi* (p. 79)

23b. Depth 43.5. Combined number of gill rakers and tubercles on upper limb 5. Body very moderately shaded; fins almost uniformly light-colored. Pectoral rays 19. (One specimen 43 mm. examined.)............ *Scorpaena albifimbria* (p. 82)

17b. Preorbital with 3 free spinous points (except in specimens of *plumieri* under 65 mm.; such small specimens being separable from the other species by the distinctive color pattern of *plumieri* and the combination of its structural characters as given under its account).

24a. Scales 42-49. Occipital pit large, comparatively rather deep except in small and very large specimens. Upper posttemporal spine rather well developed. Frontal spine nearly in a line with parietal ridge.

25a. Without a pit under eye. Eye larger than interorbital. Almost plain-colored. Head and anterior part of body rather well compressed.
Scorpaena dispar (p. 84)

25b. A pit under anterior margin of eye, just over suborbital ridge (not definitely formed in specimens under 60 mm.). Eye smaller than interorbital. Region at inner lower pectoral angle black with whitish spots (white spots not well marked in small specimens); body spotted and mottled with light and dark areas. Head and anterior part of body notably tumescent.
Scorpaena plumieri (p. 86)

26a. Occipital pit often elongate and fairly deep; small dark spots on lower part of body absent or rather sparse. Atlantic.
Scorpaena plumieri plumieri (p. 88)

26b. Occipital pit often oblong and rather shallow; small spots on lower part of body more often present and frequently rather numerous. Pacific.............. *Scorpaena plumieri mystes* (p. 92)

24b. Scales 76. Occipital pit small and shallow. Upper posttemporal spine slight. Frontal spine placed laterad of parietal ridge....... *Scorpaena microlepis* (p. 95)

1b. Lateral line unusually modified, consisting of a continuous ditchlike depression roofed over by a membranous cover without channeled scales. Supraocular, and postocular spines absent. Dorsal virtually forming two separate fins. Scales cycloid and small, 88-103. Upper 3 preopercular spines subequal or nearly so.......................... *Setarches parmatus* (p. 97)

Genus SEBASTES Cuvier

Sebastes Cuvier, Règne animal, ed. 2, vol. 2, p. 166, 1829 (two species included, *norvegicus* and *dactylopterus,* genotype by later designation).

Sebastes Bleeker, Versl. Akad. Amsterdam, vol. 9, p. 294, 1876 (*Sebastes norvegicus* Cuvier and Valenciennes, designated as genotype).

Comparison.—Among the western Atlantic scorpaenids this genus is nearest *Helicolenus,* and the differences between them are discussed under that genus. The generic characters are included below under the description of the one western Atlantic species of *Sebastes.*

SEBASTES MARINUS (Linnaeus)

Perca marina Linnaeus, Systema naturae, ed. 10, vol. 1, p. 290, 1758 (Norway, Italy).

Sebastes fasciatus Storer, Proc. Boston Soc. Nat. Hist., vol. 5, p. 31, 1854 (Provincetown, Mass.).

Sebastes marinus Jordan and Evermann (in part), U. S. Nat. Mus. Bull. 47, p. 1760, pl. 268, fig. 653, 1898 (include 2 species according to the given distribution and synonymy).—Bigelow and Welsh, Bull. U. S. Bur. Fish., vol. 40, pt. 1, p. 304, figs. 141-147, 1925 (general account, including life history).

D.XIV-XV 13-15. A.III 7-10. P.18-20. Sc.87-110. GR.9-11+23-27.

Description.—Eye large and interorbital rather wide (proportional measurements differing with population; see below). Maxillary ending at a point under pupil. Knob on chin becoming notably prolonged and tapering in large specimens. Palatine teeth present. No slit behind fourth gill arch. Gill rakers long in comparison with the other scorpaenids here treated; 9-11 on upper limb; 23-27 on lower limb, including one short, stumpy, tubercle-like outgrowth often present at anterior end of arch; 32-38 in total number. Occiput flat, without a pit. Parietal ridge long, usually continuous, ending in a single point, sometimes a second moderate spinous point a little in front of posterior spine; frontal spine in a line with postocular, placed laterad of parietal ridge; upper posttemporal ridge and spine rather well developed, lower posttemporal spinous point slight or moderate, not preceded by an external ridge; sphenotic, pterotic, and postorbital spines absent; preorbital with 2 moderate free spinous points; suborbital ridge slight, short, confined to part of cheek behind eye, without a spinous point; cleithrum with a moderate spinous point or a slight blunt projection. First preopercular spine moderately smaller than second, third subequal to first, fourth and fifth smaller but rather well developed in comparison with some other species. Subopercle very often with a moderate spinous point at its lower posterior corner, interopercle very often with a similar spine at its upper posterior corner, in juxtaposition to like spine on subopercle, sometimes a second spinous point on subopercle at a short distance above spine at angle (the 1 or 2 spines at lower part of subopercle present in addition to the 2 opercular spines on its upper part, characteristic of the family). Tentacles or flaps absent. Scales rather small, 87-110, ctenoid, with very small supplementary scales except in small specimens; snout, maxillary, mandible, soft area between mandibles, and branchiostegals partly scaled; rest of head almost completely scaled; fins moderately scaled. Penultimate dorsal spine about five-sixths as long as last; longest dorsal spine subequal to postorbital part of head or slightly shorter. Second anal spine subequal in length to third. Ventral about reaching anus, its outer angle placed moderately behind lower pectoral angle. Pectoral reaching a vertical a little behind end of ventral, its posterior margin rounded or somewhat wedge-shaped, the middle rays longest; usually its upper 2 rays unbranched, sometimes upper 1 or 3 rays unbranched, next 7-13 rays branched, lower 5-10 rays unbranched. Caudal emarginate.

Measurements of 6 American specimens 200-361 mm.; 2, 3, and 1 from samples A, B, and C, respectively (for origin of samples see below): caudal 21.0-22.5, ventral 20.0-23.5, pectoral 29.0-31.5, depth 35.5-39.5, head 36.5-39.0, maxillary 17.0-18.7, snout 8.2-9.9, eye 11.9-13.0, interorbital 7.2-8.1; snout 1.2-1.5 and interorbital 1.5-1.7 times in eye.

Measurements of 3 European specimens 258-395 mm. (sample D): caudal 21.0-22.5, ventral 20.5-24.0, pectoral 26-29, depth 33.5-34.5, head 37-38, maxillary 17.1-18.2, snout 9.7-10.4, eye 10.1-11.8, interorbital 7.7-8.4; snout 1.0-1.2 and interorbital 1.2-1.4 times in eye.

Color of preserved specimens examined a nearly uniform yellowish or golden, probably faded after long immersion in preservative. It is said to be of an orange or red color in life with some irregular dark shadings on head and back.

Development.—The pectoral rays are damaged in many small specimens examined. As far as determinable they appear to begin to branch at about 100 mm. The accessory scales begin to appear at about 120 mm.; they are very few in the smaller specimens and become very profuse with growth.

Specimens examined.—For the purpose of analyzing intraspecific population differences the specimens examined have been divided into four composite samples as follows.

Sample A: Taken off Long Island, N. Y., between latitudes 39° 49′ and 40° 05′ N., and longitudes 68° 48′ and 71° 10′ W., in 144 to 420 fathoms; 10 specimens 288-359 mm., in 9 constituent samples (31614, 31679-81, 31683, 31714-16, 35493).

Sample B: Taken on the coast of New England, from off Nantucket Island, Mass. (lat. 41° 25′ 30″ N., long. 69° 01′ W.) to Eastport, Maine; 44 specimens 40-364 mm., in 20 constituent samples (5374, 13850, 21814, 23264, 31539, 31567-8, 33381, 43078, 46075, 46079, 46084, 74117, 83928-9, 88463, 89019, 120984, 125419, 143784). Depth records are available for 9 of the 20 constituent samples and range 35-105 fathoms.

Sample C: Taken from off Cape Sable, Nova Scotia, to off St. Johns, Newfoundland, in 78-215 fathoms; 11 specimens 76-264 mm., in 7 constituent samples (21003, 33389, 38089, 46077, 84499, 84503, 134326).

Sample D: Three specimens 258-395 mm.; 2 from Bergen, Norway (17435), 1 from the North Sea (39732); no depth data available.

Comparison.—This species differs from all other western Atlantic scorpaenids as follows. The dorsal spines number 14-15. The scales are small, and it has numerous accessory scales. The gill rakers are more numerous. The count of all three characters is discontinuous as compared with the other species. It differs from its eastern Atlantic congener, *Sebastes viviparus,* in the more numerous scales, 87-110 instead of 76-82 in 4 specimens of *viviparus* examined. The latter also averages lower numbers of anal and pectoral rays, but these counts evidently overlap widely.

Populations.—While the samples examined indicate considerable differences between the local populations, the specimens are not numerous enough to draw taxonomic conclusions with anything approaching finality. These differences, as presented in tables 6-8, and the given measurements, are here briefly discussed.

Samples B and C from the western Atlantic show a significant difference in the number of dorsal rays as compared with the 3 eastern Atlantic specimens; 13 or 14 rays in 52 western Atlantic specimens as compared with 15 rays in the 3 eastern specimens. This might suggest a possible divergence of subspecies or even species magnitude. However, sample A, which was taken in deeper water off Long Island, is intermediate, having 14 or 15 dorsal rays.

The anal ray and scale counts average highest in sample A; those of the pectoral rays average lowest in sample B; those of the gill rakers on the lower limb average highest in sample C. However, the extents of divergence of these characters are evidently of low degree, below the subspecies level.

Differences in proportional measurements are contrasted above between the 3 European specimens examined and 6 American specimens of nearly comparable size. The 3 European specimens average a slenderer body, longer pectoral and snout, and smaller eye. The greatest divergence appears to be in the depth and eye measurements which were therefore determined for all available nearly comparable

TABLE 7.—*Frequency distribution of the number of dorsal spines and dorsal, anal, and pectoral rays in* Sebastes marinus, *segregated by population as delimited in the text*

	Dorsal spines		Dorsal rays			Anal rays				Pectoral rays		
Population	14	15	13	14	15	7	8	9	10	18	19	20
Sample A	1	9	..	5	5	..	5	4	1	..	9	1
Sample B	4	40	22	20	..	40	4	..	..	13	30	1
Sample C	1	10	5	5	..	5	6	..	..	..	9	2
Sample D	..	3	..	..	3	1	2	..	..	..	3	..

TABLE 8.—*Frequency distribution of the number of gill rakers on the first gill arch in* Sebastes marinus, *segregated by population*

	Upper limb			Lower limb					Total both limbs						
Population	9	10	11	23	24	25	26	27	32	33	34	35	36	37	38
Sample A	2	7	1	1	3	3	3	..	1	1	2	2	4	..	..
Sample B	4	24	13	3	12	16	7	3	..	4	11	9	11	6	..
Sample C	2	8	1	..	..	6	3	2	..	..	1	6	2	1	1
Sample D	..	2	1	1	..	1	1	..	..	1	..	1	..	1	..

TABLE 9.—*Frequency distribution of the number of scales in* Sebastes marinus, *segregated by population, the classes grouped by intervals of three*

	Distribution								
Population	87	90	93	96	99	102	105	108	111
Sample A	..	1	..	1	4	1	2	1	..
Sample B	1	3	7	5	5	1	..	..	1
Sample C	..	1	..	3	1	..	..	..	..
Sample D	..	1	1	1	..	..	..	..	..

specimens with the following result: depth 33.6-34.5 and eye 10.1-11.8 percent of the standard length in 3 European specimens 258-395 mm., as compared with 35.2-39.4 and 11.7-13.3 percent, respectively, in 20 American specimens of all populations 200-361 mm. These differences might possibly form a basis for the subspecific or specific distinction of the American and European populations; but the specimens examined are too few to enable me to draw definite conclusions.

Genus HELICOLENUS Goode and Bean

Helicolenus Goode and Bean, Oceanic ichthyology, p. 248, 1895 (genotype *Scorpaena dactyloptera* De la Roche by original designation).

Helicolenus is in a way intermediate between *Sebastes* and *Scorpaena,* agreeing with either genus in some characters and differing in others. It agrees with *Sebastes* in having the first preopercular spine shorter than the second, in having ctenoid scales, in the extent of scalation, and in lacking tentacles, and nearly agrees in the spinous armature of the head. *Helicolenus* lacks accessory scales which are present in *Sebastes.* The two genera differ further in the number of dorsal spines, anal rays, and gill rakers. The normal or usual number of dorsal spines is 12 in *Helicolenus* and 15 in *Sebastes.* The number of anal rays is almost constantly 5 in *Helicolenus,* while in *Sebastes* the number differs with the species and varies with the individual, the range being 6-10. The gill rakers are less numerous and not so well developed in *Helicolenus. Helicolenus* agrees with *Scorpaena* in normally having 12 dorsal spines and 5 anal rays, and differs from the latter in having the first preopercular spine shorter than the second, ctenoid scales, and an emarginate caudal. In general, the spinous armature of the head is not well developed in *Helicolenus* and the gill rakers better developed, as compared with *Scorpaena.* The degree of development and number of gill rakers in *Helicolenus* are rather intermediate between *Sebastes* and *Scorpaena. Helicolenus* differs from both genera in the shape and structure of its pectoral fin. The generic characters are included below in the description of the one species here treated.

HELICOLENUS DACTYLOPTERUS (De la Roche), sensu lato

D.(XI) XII (XIII) (10) 11-13. A.III (4) 5. P.17-20. Sc.60-79. GR.7-9+16-19.

Description.—Eye larger than snout. Interorbital width approximately a third to a half the eye diameter. Maxillary ending approximately under anterior margin of pupil. Palatine teeth present. No slit on inner side of fourth gill arch. Gill rakers comparatively rather slender, of moderate length at angle, rather gradually decreasing in size both ways, those at both ends short, sometimes one or two at either end very short, tubercle-like; total number of gill rakers and tubercles 7-9+16-19, 23-27 in combined number. Occiput flat, without a pit. Parietal ridge divided into two unequal parts, the anterior part long, both parts ending in spinous points; frontal spine placed laterad of parietal ridge, in a line with postocular; upper and lower posttemporal spines rather closely approximated; sphenotic and pterotic spines placed rather low, approximately on a lengthwise line through upper margin of pupil; sphenotic spine short and blunt or represented by a mere bony knob or absent; pterotic rather narrow and pointed or absent; postorbital absent; preorbital without definite spinous points, two slight or moderate blunt knobs instead; suborbital ridge with one slight or moderate point, or smooth; cleithrum without a spinous point or projection. Second preopercular spine longest, reaching about halfway to opercular margin or a little farther; first spine distinctly shorter than second, subequal to or slightly longer than third, without a supplementary spine; fourth and fifth spines moderate. Upper outer corner of interopercle often ending in a blunt angle or spinous point. Without tentacles or tabs. Scales ctenoid, 60-79; nape, opercle, and cheek virtually all scaled; interopercle partly scaled; interorbital scaled for a short distance posteriorly, its greater part scaleless; snout scaleless; maxillary partly scaled, infrequently the scales few and nearly embedded (such variants appearing scaleless on superficial examination). Dorsal typically with 12 spines; penultimate spine about four-fifths as long as last spine or slightly longer; longest dorsal spine subequal to postorbital part of head. Ventral having its outer angle a little behind lower pectoral angle, about reaching anus, varying slightly both ways. Pectoral usually having upper 2 rays unbranched, next 8-10 branched, lower 7-9 unbranched, total number of rays 17-20; the lower unbranched rays notably thickened, their distal ends detached from one another for nearly half their length; posterior margin of upper half of fin a nearly straight, slightly inclined line; the fin reaching backward approximately to a vertical through end of ventral. Caudal very moderately emarginate.

Ground color yellowish or golden; upper part of body, for a variable distance, with dark, irregular, partly anastomosing or confluent markings, the dark pigment mostly confined to margin of scales; these dark markings or shadings absent in most specimens examined (probably disappearing in preservative); posterior and greater part of mouth cavity and inner face of gill cover black or dusky, dark color especially marked on roof of cavity, sometimes the dark color hardly appreciable in specimens long in preservative. In recently preserved specimens the color in the mouth cavity is a deep bluish black.

The smaller specimens of *maderensis* have a dorsal spot as described under that subspecies. Smaller specimens of the other two subspecies are not available for comparison.

Subspecies.—The samples of this species examined are divisible into three major allopatric populations according to the following geographic regions: (1) eastern Atlantic and Mediterranean, (2) western north Atlantic, (3) Atlantic coast of South America; and are hereafter treated as subspecies, *dactylopterus, maderensis,* and *lahillei,* respectively. The subspecies differ in the relative frequency of occurrence of a spine on the suborbital ridge, in the scale count, and in some proportional measurements as stated and discussed under their accounts. In some proportional measurements *dactylopterus* and *lahillei* represent the extremes while *maderensis* is intermediate. The interorbital has the greatest average width in *lahillei* and the narrowest in *dactylopterus.* The proportional numerical value of the ventral, pectoral, depth, head, maxillary, and eye measurements average highest in *dactylopterus* and lowest in *lahillei.*

HELICOLENUS DACTYLOPTERUS DACTYLOPTERUS (De la Roche)

Scorpaena dactyloptera De la Roche, Ann. Mus. Hist. Nat. Paris, vol. 13, pl. 22, fig. 2, 1809 (Barcelona).

Helicolenus dactylopterus Norman, *Discovery* Reports, vol. 12, p. 24, 1935 (summarizes distribution; compares with the American *maderensis* and other species).

D.XII 12. A.III 5. P.19-20. Sc.66-73. GR.7-8+16-18.

Description.—Spine on suborbital ridge usually absent, sometimes present (on one side in 1 out of 7 specimens). Scales 66-73 (in 5).

Measurements of 6 specimens 197-325 mm.: caudal 25.5-28.0, ventral 22-26, pectoral 30.5-33.0, depth 33.0-36.5, head 40-45, maxillary 21.5-22.5, snout 9.0-11.0, eye 13.5-14.2, interorbital 4.4-4.7; snout 1.2-1.5 and interorbital 2.9-3.2 times in eye.

Specimens examined.—Bergen, Norway (17434). Azores (23302, 94491). Bay of Naples (48329). Genoa (29783, 124422). Received from Paris Museum, without a definite locality (42086). Total examined, 7 specimens 192-395 mm., the largest from Norway.

Comparison.—This subspecies differs from the other two here treated in usually lacking a spine on the suborbital ridge. It possibly averages a longer head, maxillary, pectoral and ventral, larger eye, narrower interorbital, fewer gill rakers, and more pectoral rays. The scale count is rather intermediate between *maderensis* and *lahillei.*

HELICOLENUS DACTYLOPTERUS MADERENSIS Goode and Bean

Helicolenus maderensis GOODE and BEAN (in part), Oceanic ichthyology, p. 250, pl. 68, fig. 244, 1895 (plate labeled *dactylopterus*, but legend to plate, on page 15*, labeled *maderensis;* for restriction of name see below).—NORMAN, *Discovery* Reports, vol. 12, p. 25, 1935 (off Long Island, N. Y.).—LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 535, p. 165, 1941 (Tortugas, Fla.).

Helicolenus thelmae FOWLER, Proc. Acad. Nat. Sci. Philadelphia, vol. 89, p. 300, fig. 5, 1937 (near Gulf Stream off Cape May, N. J.).

D.(XI)XII(XIII)(10) 11-13. A.III (4) 5. P.(17) 18-20. Sc.60-71. GR.7-9+16-18.

Description.—Spine on suborbital ridge usually present, often absent (see below for frequencies). Scales 60-71 (counted in 38 specimens; scalation incomplete in most specimens examined and number of scales not definitely determinable in such specimens).

Measurements of 12 Atlantic specimens 185-278 mm., including the lectotype, and 2 specimens 152-162 mm., the holotype and paratype of *H. thelmae:* caudal 25.5-27.5 (25.5-26.5), ventral 21-24 (23-24.5), pectoral 25.5-31.0 (28.5), depth 32-37 (35-36), head 38.5-43.5 (39.5), maxillary 20-22 (20), snout 9.6-11.1 (8.9-9.5), eye 11.7-13.7 (13.0-13.2), interorbital 4.6-5.7 (4.6-4.7); snout 1.1-1.3 (1.4-1.5) and interorbital 2.1-2.7 (2.8) times in eye. The same measurements of 5 Gulf of Mexico specimens 195-238 mm. fall within the range of the above large specimens, except as follows: pectoral 28.0-31.5, maxillary 21.0-22.5, eye 13.4-14.7, interorbital 4.2-5.3; snout 1.4 and interorbital 2.6-3.4 times in eye.

Small specimens with a dark spot on dorsal between seventh or eighth and eleventh spines; the spot beginning to disappear at about 100 mm., often well marked in specimens up to 150 mm., and a more diffuse spot sometimes persisting up to 200 mm.

Specimens examined.—In the U. S. National Museum, 177 specimens in 54 constituent samples. The great majority were taken by the *Albatross* and the *Fish Hawk* at a number of stations. The geographic range of these specimens is from off Cape Cod, Mass. (41° 49′ N., 65° 49′ 30″ W.; 143291) to off Tortugas, Fla.; and off Egmont Key and Cape San Blas, Fla., and the Mississippi Delta in the Gulf of Mexico. Besides the preceding large sample the following 4 specimens were examined. About 70 miles southeast of Cape May, N. J. (A.N.S.P. 68261 and 68262, the holotype and paratype, respectively, of *H. thelmae*). Off Massachusetts Bay (U.M.M.Z. 157066; lat. 42° N., long. 68° W., 85-95 fathoms, fishing boat *Mary and Josephine;* U.M.M.Z. 157067; lat. 42° 20′ N., long. 68° 50′ W., 106 fathoms, fish boat *Bonaventure*). The last specimen constitutes the northernmost record. The recorded vertical range is 70-373 fathoms. Total examined, 181 specimens 29-444 mm., the largest from off Long Island, N. Y. (21824).

Populations.—According to the measurements given above, the Gulf population of this subspecies differs from that of the Atlantic in averaging a larger eye and narrower interorbital. The frequency of occurrence of a spinous point on the suborbital ridge in the Gulf population, judged by the 5 specimens examined, seems to be not much different than in the Atlantic population.

Lectotype.—In the original account of *maderensis* only western Atlantic localities are enumerated for the specimens examined. However, the authors state that the same species occurs in Madeira, and they cite the account of *Sebastes imperialis* of Lowe as referring to their *maderensis*. Their account, consequently, is a composite one, referring to more than one subspecies, and it becomes necessary to restrict the use of the name *maderensis*. Therefore, U.S.N.M. No. 26627 is hereby designated as the lectotype. It is one of Goode and Bean's original specimens, apparently the one figured, and its data are as follows: *Fish Hawk* station 897, lat. 37° 25′ N., long. 74° 18′ W., off Hog Island, Va., 158 fathoms, 200 mm. As restricted, the name *maderensis* is inappropriate for a common fish living off the east coast of the United States; but all the original specimens came from this region.

Comparison.—Norman and also Longley (cited above) treat the western Atlantic *maderensis* as of specific rank. Norman states that *maderensis* differs from *dactylopterus* in having a smaller eye, in constantly having a spine on the suborbital ridge, in the less deeply concave interorbital, and possibly in having a little larger scales. Longley distinguishes *maderensis* from *dactylopterus* by its smaller eye and by its having a spine on the suborbital ridge. However, an examination of more extensive samples than those available to the above authors lead to the following conclusions.

The depth of the interorbital concavity is largely a matter of individual variability and can hardly be used as a specific character. The difference in the size of the eye does seem to have some value, 13.5-14.2 in 6 European specimens, and 11.7-13.7 in 12 specimens of comparable size from the Atlantic coast of the United States. However, when the measurements of the eye of the 17 specimens are arranged in order of magnitude, 3 European and 2 American Atlantic specimens intergrade, which indicates a degree of divergence of less than subspecies magnitude. Moreover, in 5 comparable specimens from the Gulf of Mexico the eye measurement is 13.4-14.7, very nearly the same as in the European specimens. It is evident that the size of the eye differs with the minor population and cannot be used even in subspecific division. The scales in 5 European specimens number 66-73, while in 38 American fish the range is 60-71, and this difference also is obviously below the subspecies level.

The difference showing the greatest divergence apparently refers to the spinous point on the suborbital ridge, but this character also intergrades considerably. Of 181 specimens examined from the western Atlantic, 124 have a spinous point on both sides, 41 have the spine on one side only, and 16 lack a spine on both sides. The percentages of these three categories of specimens in the entire composite sample are: 69, 23, and 9, respectively. Of 7 European specimens examined only one has a spinous point on one side only. In the absence of an adequate sample from Europe, to express the extent of divergence in numerical terms, the number of observations, which is twice the number of specimens, may be used as a base. Of 362 observations on western Atlantic specimens, 73, or 20.17 percent, are zero and 289 are 1; while the corresponding observations on European specimens are 13 and 1, respectively, that is, the intergrading observation is 7.14 percent of the sample. The index of intergradation then is 14, and concomitantly the index of divergence is 86 (Ginsburg, 1938), which is not more than of subspecies magnitude, and the populations are so treated here.

Synonymy.—The 2 types of *thelmae* were examined and their data included in this account. The holotype has a blunt projection in the normal position of the spinous point on the suborbital ridge. It is included in the above enumeration with the specimens having a spine, as the development of this spine shows all degrees of difference from a sharp point to a blunt projection. In the paratype the interorbital ridge is smooth on both sides as in 15 other individual variants of *maderensis*. The two types seemingly lack scales on the maxillary, while *dactylopterus*, sensu lato, including *maderensis*, normally has such scales. However, the scales in *maderensis* and the two other subspecies are more or less deciduous. Other specimens of *maderensis* examined seemingly lack scales on the maxillary. Besides, the holotype of *thelmae* shows faint traces on the right maxillary of scales having been present. In measurements, counts, the presence of a diffuse dorsal spot, and other characters, the two types of *thelmae* agree with the common *maderensis* and there is no question that they belong to this subspecies.

HELICOLENUS DACTYLOPTERUS LAHILLEI Norman

Helicolenus lahillei NORMAN, *Discovery* Reports, vol. 16, p. 124, fig. 68, 1937 (coasts of Uruguay and northern Argentina).

Helicolenus uruguayensis FOWLER, Proc. Acad. Nat. Sci. Philadelphia, vol. 95, p. 326, figs. 18, 19, 1943 (off Uruguay).

D.XII-XIII 11-13. A.III 5. P.18-19. Sc.68-79. GR.7-8+17-19.

Description.—Spinous point on suborbital ridge usually present, sometimes absent (of 9 specimens examined, 7 have a spine on both sides and 2 lack it on one side only). Scales 68-79 (in 4).

Measurement of 9 specimens 208-290 mm.: caudal 25-29, ventral 20-23, pectoral 27.0-30.5, depth 32.0-35.5, head 37.0-41.5, maxillary 18.5-20.5, snout 8.5-10.0, eye 11.4-13.0, interorbital 4.6-6.2; snout 1.2-1.5 and interorbital 1.9-2.7 times in eye.

The shadings on the body, as described under the account of *dactylopterus,* sensu lato, is usually somewhat better developed in *lahillei* than in the other two subspecies in the preserved specimens examined.

Specimens examined.—Off Río de la Plata, lat. 36° S., long. 54° W., 50 meters, F. Filippone (85509, 290 mm.). Five specimens 208-252 mm. obtained in Uruguay during 1921-22, probably in the Montevideo market, by Hugh M. Smith (86696-86700, inclusive). Uruguay (A.N.S.P. 70325, the holotype 286 mm., and A.N.S.P. 70326-7, two paratypes 227-229 mm., of *uruguayensis*).

Comparison.—This subspecies, like *maderensis,* usually has a spine on the suborbital ridge. It differs in having a higher scale count, 68-79 instead of 60-71. While the specimens with a fairly complete scalation examined are not enough to determine the precise degree of divergence, it is apparently not greater than subspecies magnitude. This subspecies differs from the other two in proportional measurements also, as stated under the account of the species and as may be gathered by comparing the measurements here given for the three subspecies. In measurements also *lahillei* is nearest *maderensis.*

Nomenclature and synonymy.—The three types of *uruguayensis* were examined and their data are included in this account, but the types of *lahillei* were not examined. Fowler, in describing his *uruguayensis,* calls attention to some discrepancies in Norman's account of *lahillei,* based mainly on a comparison of his specimens with Norman's published figure. However, allowing for imperfections that nearly always are found in pen-and-ink drawings of fish, and taking Norman's account of *lahillei* in its entirety, it is evident that it refers to the subspecies here described, which seems to be common on the coast of Uruguay.

Genus SCORPAENODES Bleeker

Scorpaenodes Bleeker, Nat. Tijdschr. Ned. Ind., vol. 13, p. 371, 1857 (genotype *Scorpaenodes polylepis* (Bleeker) = *Scorpaena polylepis* Bleeker by monotypy; name merely listed, no description).

Definition.—Eye moderately larger than snout. Interorbital one-half the eye diameter or moderately narrower. Maxillary ending under middle or posterior margin of eye. Palatine teeth absent (the only one of the present genera lacking palatine teeth). Small slit behind fourth gill arch present or absent. Gill rakers moderate at angle becoming very short, tubercle-like at ends of first gill arch; tubercles well separated and individually countable in the few specimens examined; gill rakers and tubercles combined 4-8 + 10-13, or 15-20 in total number. Occiput flat, without a pit. Interorbital with two bilaterally placed ridges, one on both sides of midline, slightly or well developed, ending in a spinous point, or the point virtually absent; parietal ridge divided into subequal parts, both ending in spinous points; frontal spine nearly alined with postocular, placed laterad of parietal ridge; lower posttemporal present, upper one present or absent; sphenotic and postorbital spines inconspicuous, in form of a group of a few slight spinules, asperities, or tuberosities; pterotic large or small; pterotic, lower posttemporal and supracleithral spines almost on same lengthwise line; preorbital with two broad, lobelike projections, without spinous points; suborbital ridge well developed, its spinous points differing widely with the species; supracleithral spinous point notably long, tapering, and sharp; cleithrum with a moderate tapering projection, sharply pointed or rather blunt. Preopercle having first spine longest, supplemental spine varying with the individual, present or absent (sometimes varying on both sides of same specimen); second spine placed near first spine; third spine in form of a rather broad projection without a sharp point; fourth and fifth spines virtually absent or slightly developed. Tentacles and other appendages comparatively few. Scales 40-42, ctenoid on body, occiput, opercle, and cheek; mostly cycloid on chest and fleshy pectoral base; opercle, and cheek to about under middle of eye nearly all scaled; interorbital, snout, and maxillary scaled or nearly scaleless; interopercle scaleless. Dorsal spines 13; emargination between spinous and soft parts rather well developed, penultimate spine two-fifths to seven-tenths as long as last spine; longest dorsal spine shorter than postorbital part of head. Second anal spine longer than third. Ventral reaching anus or a little short, its outer angle placed under lower pectoral angle. Pectoral nearly wedge-shaped, the longest rays near its middle, reaching a vertical through beginning of anal or a little short; with 17-19 rays, upper 5-7, except uppermost 1 or 2, branched. Caudal rounded.

Pectoral rays and gill rakers.—As the number of available western Atlantic specimens belonging to *Scorpaenodes* are very few, the pectoral rays and the gill rakers, being of importance in distinguishing the species, have been counted on both sides of every specimen and all the counts entered in the tables and in the accounts of the species. The gill-raker count differs rather widely on both sides of the type of *russelli,* 10 on the lower limb of the right side, 13 on the left.

Comparison.—*Scorpaenodes* differs from all other known western Atlantic scorpaenid genera in lacking palatine teeth and normally having 13 dorsal spines.

Speciation.—Five western Atlantic species of *Scorpaenodes,* namely, *tridecimspinosus, caribbaeus, russelli, triacanthus,* and *floridae,* have been successively described from time to time by different authors. In most instances the successive new species were established on the basis of published accounts, rather than by direct comparison of specimens. I examined and compared directly a cotype of *tridecimspinosus,* the holotype and a paratype of *floridae,* and the holotypes of the other three species. This study has shown that *caribbaeus, russelli,* and *triacanthus* are based on specimens of the same species which is different from *tridecimspinosus;* while the two types of *floridae* are doubtfully different specifically from *tridecimspinosus.* That is, based on a direct comparison of the types, not more than three species of *Scorpaenodes* are now known from the western Atlantic, one of which is doubtfully distinct. The species are compared below in some detail under their accounts.

SCORPAENODES CARIBBAEUS Meek and Hildebrand

Scorpaenodes caribbaeus MEEK and HILDEBRAND, Publ. Field Mus. Nat. Hist., zool. ser., vol. 15, pt. 3, p. 847, pl. 82, September 1928 (Toro Point, Canal Zone).

Scorpaenodes russelli BEEBE and TEE-VAN, Zoologica, vol. 10, No. 1, p. 189, fig., December 1928 (Port au Prince, Haiti).

Scorpaenodes triacanthus PARR, Bull. Bingham Oceanogr. Coll., vol. 3, art. 4, p. 115, fig. 30, 1930 (Cat Island, Bahamas).

D.XIII 9. A.III 5. P.18-19. Sc.41-42. GR.6-8+10-13.

Description.—Eye a little larger than snout. Interorbital about two-fifths the eye. Maxillary ending under middle of eye. Small slit behind fourth gill arch present. Most spines on head, including the interorbital ridges and spinous points, well developed; lower posttemporal well developed, upper one small or absent; an extra spinous point about midway between posterior parietal and lower posttemporal ridges (latter spine bifid on right side of type of *caribbaeus* and absent on left side of type of *triacanthus;* an extra small spinous point a little way below posterior parietal ridge on right side of type of *caribbaeus*); pterotic spine notably well developed; suborbital ridge with 4 or 5 spinous points; 2-4 other points on a line parallel to main ridge and at a very short distance below it, placed under anterior part of eye (on right side of type of *caribbaeus* an extra spinous point over main ridge slightly behind a vertical through posterior margin of eye). Small tentacles or tabs placed at some of the spines on the head, including the supraocular spine, and along the course of the lateral line. Interorbital, snout, and cheek under anterior part of eye with very small nonimbricate scales; maxillary for a moderate extent along its upper part with similar small scales present or absent. Penultimate dorsal spine about two-thirds as long as last spine. Ventral reaching anus or falling slightly short. Pectoral reaching a vertical through base of first anal spine or falling slightly short; its upper 2 rays unbranched, next 6-7 rays branched, lower 9-11 rays unbranched.

Measurements of 2 specimens 63.5-68.7 mm. in standard length, the caudals damaged, and 1 specimen 48 mm. or 36.5 mm. in standard length: caudal (32.5), ventral 26 (31), pectoral 31.5 (35.5), depth 37.5-39.0 (39.5), head 44-45 (47.5), maxillary 21-23 (24.5), snout 11.8-13.2 (12.3), eye 13.8-14.2 (14.8), interorbital 5.5-5.8 (7.4); snout 1.1-1.2 (1.2) and interorbital 2.4-2.6 (2.0) times in eye.

Rather dark brownish above, somewhat lighter below; dorsal dark, the pigment somewhat more concentrated between eighth and ninth and twelfth spines, without a definite spot; pectoral, soft dorsal, and caudal with small spots; no other distinctive color marks.

Development.—The preceding account is based in large part on two specimens 63.5-68.7 mm. in standard length (the holotypes of *caribbaeus* and *russelli,* respectively). A considerably smaller specimen, 36.5 mm. in standard length (the holotype of *triacanthus*), differs from the two larger specimens as follows. The very small scales on the snout and interorbital are as yet undeveloped, but some tiny papillae are present, which are seemingly destined to become scales. The maxillary about reaches to under posterior margin of eye. The suborbital and pterotic spinous points are not as well developed. The caudal peduncle is abruptly lighter. The pectoral and, to a lesser extent, the soft dorsal, anal, and caudal have a dark area near their base, and the small spots on the fins are much fewer. Differences in some proportional measurements are indicated above. All these differences are readily ascribable to growth changes. There are no well-marked specific differences such as distinguish scorpaenid species. It is therefore concluded that the holotype of *triacanthus* is a small specimen of *caribbaeus,* although a complete series is not available to trace growth changes more definitely.

Specimens examined.—Toro Point, Canal Zone (81619, holotype of *caribbaeus,* 63.5 mm. in standard length). Port au Prince Bay, Haiti (N.Y.Z.S. 7207, holotype of *russelli,* 68.7 mm. in standard length). Cat Island, Bahamas (B.O.C. 2533, holotype of *triacanthus,* 48 mm.). The type of *caribbaeus* is an abnormal specimen having the soft fins malformed, apparently a result of either an injury at some past time in life or a derangement during development. Therefore, its soft dorsal and anal counts and the ventral measurement is not included in the account of the species. But the dorsal and anal spines, the scalation, the shape of the body and head, and the spinous armature of the latter are evidently normal.

Comparison.—This species differs from *tridecimspinosus* in a number of characters, as follows. Some spinous points are present under the anterior main part of the suborbital ridge. The interorbital ridges are better developed and they end in well-developed spinous points. The pectoral rays and the gill rakers on the upper limb are more numerous. The minute scalation on the snout and interorbital is better developed. It has a small slit behind the fourth gill arch.

Synonymy.—A direct comparison of the types of *russelli* and *caribbaeus* shows without a doubt that both specimens belong to the same species. Its presumed specific differences given in the original description of *russelli,* based on a comparison with rather inadequate accounts of previously established species, do not hold, or the differences are based on individual variation.

S. triacanthus was established chiefly because it was supposed that it has 3 opercular spines. However, an examination of the type shows that it has only 2 spines in the opercle, like the other species of its family. Apparently the supracleithral spine was assumed to be a third opercular spine. The type of *triacanthus* is evidently a half-grown specimen of *caribbaeus* as discussed above.

SCORPAENODES TRIDECIMSPINOSUS (Metzlaar)

Scorpaena tridecimspinosa Metzlaar, Rapp. Vissch. Kol. Curaçao, edited by J. Boeke, vol. 2, pt. 1, p. 146, fig. 44, 1919 (Aruba and Bonaire Islands, D.W.I.).

D.XIII 9. A.III 5. P.17. Sc.41. GR.5+10.

Description.—Eye rather large, moderately larger than snout. Interorbital slightly less than half the eye. Maxillary ending under posterior margin of eye. No slit behind fourth gill arch. Interorbital ridges slight, not ending in definite spinous points; upper posttemporal absent; pterotic small; suborbital ridge with three moderate spinous points. A foliar tentacle at base of supraocular spine, much expanded for its distal and greater part, digitated; a similar narrower tentacle at lower posterior corner of preorbital bone; a moderate elongate tentacle at postocular spine; a foliar sessile tentacle on eyeball nearly over anterior margin of pupil; a similar larger tentacle attached to posterior rim of anterior nostril; small tentacles at other spines on head. Anterior and greater part of interorbital, snout, and cheek under anterior part of eye with numerous papillae, some of them in form of tiny scalelike structures; no scales on maxillary. Penultimate dorsal spine about half as long as last spine. Ventral falling a little short of anus. Pectoral a little short of a vertical through first anal spine; its upper ray unbranched, next 6 or 7 rays (differs on both sides of same specimen) branched, lower 9 or 10 rays unbranched, notably thickened.

Measurements of one specimen 42.8 mm. in standard length, the caudal damaged: ventral 27.5, pectoral 30, depth 36, head 44.5, maxillary 25.5, snout 12.6, eye 14, interorbital 6.8; snout 1.1 and interorbital 2.1 times in eye.

Brownish, nearly uniform, slightly and irregularly shaded; a broad transverse whitish area under pupil to maxillary; dark pigment somewhat more concentrated at posterior part of spinous dorsal; pectoral and soft dorsal with small, rather faint brownish spots. The figure of the species published by Metzlaar shows rather sharply contrasting light and dark shades with 2 dark, broad cross areas on posterior part of body and caudal peduncle.

Specimen examined.—Bonaire Island, D.W.I. (160660, cotype of *tridecimspinosus*).

Comparison.—This species is compared with *caribbaeus* and *floridae* under their accounts.

SCORPAENODES FLORIDAE Hildebrand

Scorpaenodes floridae HILDEBRAND, Carnegie Inst. Washington Publ. 517, p. 251, fig. 14, 1940 (Tortugas, Fla.).

D.XIII 8-9. A.III 5. P.17. Sc. about 40-41. GR.4-5+11.

Description.—Eye rather large, snout about four-fifths the eye diameter. Interorbital width equaling one-half the eye or a little narrower. Maxillary ending under posterior margin of eye. No slit behind fourth gill arch. Interorbital ridges slight or moderate, their spinous points moderate or virtually absent; lower posttemporal moderate, upper one absent; pterotic spine very moderate; suborbital ridge with one moderate spinous point, at its posterior end. A moderate, elongate tentacle at base of supraocular spine; a similar smaller tentacle at posterior lower angle of preorbital; a foliar sessile tentacle on eyeball nearly over anterior margin of pupil; tentacle at anterior nostril moderately expanded distally; very small tentacles or tabs at preocular and some other spines on the head. Anterior and greater part of interorbital, snout, and cheek under anterior part of eye with very small, nonimbricate, widely spaced scales and some papillae; no scales on maxillary. Penultimate dorsal spine about two-fifths as long as last spine. Ventral about reaching anus. Pectoral reaching to over base of first or second anal spine; its upper 1 or 2 rays unbranched, next 5-7 rays branched, lower 9-10 rays unbranched.

Measurements of 2 specimens 51-58 mm.: caudal 28-29, ventral 27-30, pectoral 34.5, depth 38.0-39.5, head 44-45, maxillary 25, snout 10.9-11.2, eye 13.1-14.2, interorbital 6.6; snout 1.2-1.3 and interorbital 2.0-2.2 times in eye.

The two specimens examined almost uniformly yellowish, apparently faded; a trace of brown pigment between the eighth or ninth and eleventh dorsal spines suggesting the possible normal presence of a spot in that position.

Specimens examined.—South of Tortugas, Fla., 45 fathoms (108875, the holotype; 108876, the paratype).

Comparison.—It is doubtful whether *floridae* represents a valid species, distinct from *tridecimspinosus*. The two type specimens of *floridae* differ from the paratype of *tridecimspinosus* examined as follows. The suborbital ridge has only 1 spinous point, instead of 3. The interorbital ridges and spines are somewhat better developed. The tentacles on the head, especially those at the supraocular spine, the preorbital bone, and the anterior nostril, are not as well developed. However, judged by intraspecific variability of some other scorpaenid species, it seems possible that an examination of an adequate sample of *tridecimspinosus* will show that the differences outlined above are nothing more than differences between individuals of the same species.

Genus **PONTINUS** Poey

Pontinus Poey, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 172, 1860 (genotype *Pontinus castor* Poey by monotypy, the only other species, *pollux*, included in original account being a *species inquirendae*).—Jordan and Gilbert, U. S. Nat. Mus. Bull. 16, p. 673, 1883 (*Pontinus castor* Poey designated genotype).

Definition.—Eye subequal to snout or smaller, except in *macrolepis* varying to larger than snout. Interorbital about a third to half the eye. Maxillary ending under middle to under posterior margin of eye. Palatine teeth present. A small slit behind fourth gill arch, either open altogether or bridged over its outer side by a thin, easily torn membrane. Upper limb with 3-6 end gill rakers short, tubercle-like, but individually readily distinguishable and countable; lower limb with 3-6 tubercles at end, some of them only slightly raised above surface of arch or much expanded lengthwise along arch, sometimes difficult to distinguish individually; combined number of gill rakers and tubercles 5-8+12-15, or 18-22 altogether. Occipital region flat, without a pit. Nasal spine small or well developed. Parietal ridge divided into two parts, both ending in spines, the anterior part somewhat longer; frontal spine in a line with postocular, placed a little laterad of parietal ridge; upper posttemporal very small or absent, lower posttemporal well developed; sphenotic in form of 2 parallel, transverse rows of small spinous points, growing smaller downward, 1 to 6 points in a row; pterotic ridge and spine well developed; a ridge between sphenotic and frontal spine fairly developed or slight; postorbital in form of a group of slight asperities, or very slight tubercle-like projections, or absent; preorbital with 2 free spinous points, the posterior better developed than anterior and directed backward, smaller anterior spine directed downward or backward depending on the species; suborbital ridge well developed, typically with 3 or 4 spinous points; spinous point on cleithrum moderate or rather well developed. First preopercular spine longest, supplemental spine usually present, sometimes absent as an individual variation; second spine smaller than third or absent, distance between first and third spines characteristically a nearly straight transverse line, the third spine marking a comparatively sharp turn in direction of preopercular margin downward and forward; fifth spine variable, well developed or absent. Tentacles sparsely developed. Scales ctenoid, 42-54; opercle and nape all scaled; cheek nearly all scaled posteriorly, naked or incompletely scaled under anterior part of eye; interorbital scaled posteriorly, scaled or naked for its larger part anteriorly; snout more or less scaled or scaleless; interopercle with a few scales posteriorly; maxillary scaleless. Dorsal typically with 12 spines; with 9 or 10 rays, depending on the species; penultimate spine about two-thirds to five-sixths as long as last spine; shape of spinous dorsal differing with the species. Second anal spine notably longer than third, except moderately so in *castor*. Ventral reaching anus or falling slightly short, its outer angle under lower pectoral angle or slightly more forward. Pectoral irregularly wedge-shaped, the longest rays near its middle, usually falling short of a vertical through base of first anal spine, often about reaching this vertical; usually with 17 or 16 rays, depending on the species, all unbranched. Caudal truncate, slightly rounded, or very moderately emarginate.

Comparison.—This genus differs from the other western Atlantic scorpaenid genera in having all pectoral rays unbranched. It is most nearly related to *Neomerinthe,* as discussed under that genus.

Western Atlantic species.—Four western Atlantic species of *Pontinus* are here treated. A fifth species has been described, namely, *Pontinus corallinus* Miranda Ribeiro (1915, p. 4, photo); but no specimens are available for study. The general aspect of the published photograph of *P. corallinus* rather agrees with *Pontinus macrolepis;* but Miranda Ribeiro ascribes to his fish 6 gill rakers and 4 rudiments on the lower limb, and 2 and 4, respectively, on the upper limb. The combined number of gill rakers and rudiments on the lower limb and the total combined number on both limbs is less than in the four species of *Pontinus* here treated (compare with tables 4 and 5).

PONTINUS MACROLEPIS Goode and Bean

Pontinus macrolepis Goode and Bean, Oceanic ichthyology, p. 257, pl. 69, fig. 247 (off Yucatan).—Evermann and Marsh, Bull. U. S. Fish. Comm., vol. 20, pt. 1, p. 280, col. pl. 43, (1899) 1902 (Mayagüez Harbor, Puerto Rico).

D.XII 9. A.III 5. P.15-16. Sc.45. GR.7-8+12-13.

Description.—Eye a little larger than snout or subequal to it. Interorbital less than a third the eye diameter. Maxillary ending under posterior margin of pupil or a little behind. Nasal spine well developed; upper posttemporal spine small, sometimes absent; preorbital spines well developed, the anterior one directed backward; suborbital ridge usually with 3 spinous points, sometimes 4. Second preopercular spine present, placed nearer first than third spine; fifth spine very moderate or absent. A tentacle at supraocular spine usually present, slender or moderately thick, short or long; a short tentacle at preocular and posterior preorbital spine present or absent. Scales on cheek mostly ctenoid, those on anterior part of chest and pectoral base mostly cycloid; snout and greater part of interorbital scaleless. Third dorsal spine longest, subequal to postorbital part of head, moderately longer than fourth, thence gradually decreasing; penultimate spine about five-sixths as long as last spine. (Caudal damaged in the 4 specimens examined, its shape not definitely determinable.) Preserved specimens examined about uniformly yellowish, without color marks.

Measurements of 4 specimens 51-137 mm.: caudal 25-27, ventral 25.5-27.5, pectoral 27.5-30.5, depth 32.5-35.5, head 45-47, maxillary 22-24, snout 12.9-13.2, eye 12.9-15.4, interorbital 4.0-4.7; snout 1.0-1.2 and interorbital 3.1-3.6 times in eye.

Specimens examined.—Off Cozumel Island, Mexico (39324, the type). Off Havana, Cuba (100381). Off Anegada Island, Virgin Islands (117879). Mayagüez Harbor, Puerto Rico (126131). Total examined, 4 specimens 51-137 mm., taken in 122-224 fathoms.

Comparison.—This species has 15-16 pectoral rays instead of 17-18 in its three congeners (rarely 16 in *longispinis,* see table 1). The eye averages larger than in the three other species. It nearly agrees with *rathbuni* and *longispinis* and differs from *castor* in having the snout a little shorter than or subequal to the eye. Like *castor* it has 3 spinous points on the suborbital ridge, while *rathbuni* and *longispinis* usually have 4.

PONTINUS LONGISPINIS Goode and Bean

Pontinus longispinus Goode and Bean, Oceanic ichthyology, p. 258, pl. 68, fig. 246, 1895 (off Cape San Blas, Fla.).

D.XII 9 (10). A.III 5. P.(16) 17 (18). Sc.47-51. GR.6-7+12-15.

Description.—Eye a little smaller than or subequal to snout. Interorbital about a half to a third the eye diameter. Maxillary ending under middle of eye or posterior margin of pupil. Nasal spine small; upper posttemporal spine usually present, small, pointed or blunt, sometimes absent; preorbital spines well developed, the anterior one usually directed downward or slightly forward; suborbital ridge usually with 4 spinous points, the anterior one sometimes absent. Second preopercular spine in the larger specimens (see below) usually very small, often absent on one or both sides; fifth preopercular spine small but sharp. Tentacle at supraocular spine very slender and small or absent, of moderate length and slender in small specimens (skin partly destroyed in most specimens examined and this statement based on fragmentary data). Scales on cheek, chest, pectoral base, interorbital, and snout mostly ctenoid; interorbital and snout incompletely scaled for their greater part, scales on anterior part of snout minute. First dorsal spine about two-thirds as long as second. Third spine prolonged in specimens over 90-110 mm.; becoming notably long in large specimens, longer than postorbital part of head, nearly twice as long as second spine, reaching base of eighth to tenth spine when depressed.

Fourth spine a little longer than second; gradually decreasing in length from fourth backward; penultimate spine about three-quarters as long as last spine; in small specimens about 100 mm. or smaller, third spine only a little longer than fourth, the spines gradually decreasing in length from third to penultimate spine. Caudal very moderately emarginate with the upper rays slightly longer than lower.

Measurements of 5 specimens 123-178 mm.: caudal 25.5-28.5, ventral 23-25, pectoral 27-29, depth 31.5-33.0, head 41-45, maxillary 19.5-21.5, snout 12.6-13.1, eye 11.8-13.6, interorbital 4.3-5.0; eye 0.9-1.1 times in snout, and interorbital 2.4-3.1 times in eye. Two specimens 215-220 mm.: pectoral 29.5-30.0, depth 28.0-31.5, head 40.5-42.5, eye 11.5-12.1, snout 13.4; eye 1.0-1.3 times in snout, interorbital 2.1-2.7 times in eye; other measurements falling within range of variation of smaller specimens.

Ground color light yellowish; upper two-thirds of body with irregularly scattered small brownish spots, their number very variable, sometimes rather profuse, sometimes nearly confined to a row along course of lateral line or nearly absent; small, rather diffuse spots on caudal and dorsal, also variable in number. Small specimens, about 45 mm. or less, with a large dark blotch between sixth or seventh and ninth or tenth dorsal spines; otherwise not spotted.

Development.—In very small specimens, 24-30 mm., the upper 3 preopercular spines are in general approximately equal. With growth, the second and third spines become shorter in relation to the first. With further growth, the second spine decreases in length; it becomes smaller than the third at about 60 mm.; and is very small or altogether absent on one or both sides in larger specimens. (The development of the third anal spine is discussed above under the family account.)

Specimens examined.—Off the following localities: Bull Island, S. C. (151867). Savannah, Ga. (91403). Melbourne (155299), Tortugas (117144-5 and 117149-50), Cape San Blas (U.S.N.M. Nos. 39322-3, types; 46094, 155296, 155298, 157539), Pensacola (155295, 155297), and Santa Rosa Island (157540-1), Fla. Mississippi Delta (155287-90, inclusive) and Point au Fer (155291), La. Padre Island, Tex. (155292-4, inclusive; 157542). Total examined, 79 specimens 24-220 mm., the largest from off Tortugas. Available depth records range 40-142 fathoms. This is apparently a rather common species offshore. The majority of the specimens examined were collected by the *Pelican* and the *Oregon*.

Comparison.—This species differs from its three western Atlantic congeners in having the third dorsal spine notably prolonged, generally in specimens over 100 mm. It is structurally nearest *rathbuni* with which it is compared under the account of the latter.

PONTINUS RATHBUNI Goode and Bean

Pontinus rathbuni GOODE and BEAN, Oceanic ichthyology, p. 255, pl. 68, fig. 245, 1895 (off Cape Hatteras, N. C.).

D.(XI) XII 9 (10). A.III 5. P.17 (18). Sc.43-48. GR.5-8+12-14.

Description.—Body averaging deep. Eye a little smaller than or subequal to snout. Interorbital equaling one-third the eye diameter or a little broader, sometimes slightly narrower. Maxillary ending nearly under posterior margin of eye or a little short. Nasal spine well developed; upper posttemporal spine absent or slightly developed; preorbital spines well developed, the anterior one usually directed sharply backward; suborbital ridge with 4 spinous points (a fifth point observed in one specimen). Second preopercular spine present; fourth and fifth spines directed downward or slightly backward; the fifth smaller than fourth, sometimes obsolescent. A thick, broad, moderately long tentacle at supraocular spine, sometimes forked distally and ending in two expanded lobes; shorter, slenderer tentacles at preocular, preorbital, and preopercular spines present or absent. Scales on cheek, chest, pectoral base, interorbital and snout mostly ctenoid; interorbital and snout scaled for their greater part, but scalation not continuous, more or less interrupted, leaving irregular, variable, bare spaces. Third dorsal spine longest, subequal to postorbital part of head; fourth slightly shorter or subequal to third, thence rather rapidly graduated, growing smaller backward; penultimate spine about three-fifths as long as last spine. Caudal truncate.

Measurements of 5 specimens 120-180 mm.: caudal 24.5-27.0, ventral 24.5-27.5, pectoral 27.0-29.5, depth 33.5-39.0, head 43-45, maxillary 22-23, snout 12.8-14.4, eye 11.0-13.2, interorbital 3.9-4.9; eye 1.0-1.3 times in snout and interorbital 2.3-3.2 times in eye.

Specimens of comparatively recent preservation having body irregularly shaded with dusky, especially on its upper part, against a yellowish background; some small dusky spots irregularly spaced along course of lateral line; caudal with some small, faintly dusky spots, sometimes well marked along edge of fin. Specimens long in preservative plain yellowish without shadings or spots. Small specimens, about 40 mm. or less, with a dusky smudge between sixth and ninth dorsal spines; pectoral with an irregular, elongate, dusky, smudged area at its middle and near its base, persisting up to about 60 mm., and as a slight trace up to about 125 mm.

Development.—The small specimens examined, although most of them not in good condition, suggest that the development of the spines on the preopercle is similar to that described above for *longispinis.*

Specimens examined.—From off the following localities: Cape Charles (157567; lat. 37° 07′ 40″ N., long. 74° 35′ 40″ W.) and Cape Henry (120995), Va. Cape Hatteras (39325, the holotype; 84521, 101522, 143055) and Cape Lookout (144573), N. C. Bull Island, S. C. (151866). Palm Beach (153124), Vaca Key (153125), Key West (72985, 73257, 143123), and Ten Thousand Islands (C.N.H.M. 46216), Fla. Dauphin Island, Ala. (47643). Total examined, 28 specimens 19-180 mm., the largest from off Bull Island. Recorded depths range 49-122 fathoms. While not rare offshore this species evidently is not as common as *longispinis,* especially in the Gulf whence only 2 small specimens 58-72 mm. were examined.

Table 10.—*Frequency distribution of the body depth in* Pontinus longispinis *and* P. rathbuni, *expressed as a percentage of the standard length and segregated into size groups*

Species	Standard length in mm.	Distribution											
		28	29	30	31	32	33	34	35	36	37	38	39
longispinis	148-174	1	1	3	2	4	..	1	..	..	..	..	..
longispinis	95-146	..	1	8	13	12	7	..	..	..	..	..	..
rathbuni	96-145	..	..	..	..	..	1	1	2	2	3	..	1
longispinis	51- 93	..	1	3	1	2	7	1	..	..	..	..	..
rathbuni	55- 83	..	..	..	..	..	..	1	3	1	..	..	..
longispinis	21- 36	..	..	..	..	..	3	2	1	..	..	..	..
rathbuni	18- 37	..	..	..	..	..	..	3	3	3	1	1	..

Comparison.—This species is nearest *longispinis* structurally. The larger specimens, those over 110 mm. or so, are readily separable by the length of the third dorsal spine which is conspicuously prolonged in *longispinis.* This species has a deeper body than *longispinis* (table 10), which is useful in separating specimens over 65 mm., but the two species intergrade somewhat in this character, and it becomes of only slight value in specimens under 50 mm. The direction of the first preorbital spine is of some specific value; it is directed backward in *rathbuni* and typically downward or slightly forward in *longispinis.* The tentacle at the supraocular spine which is usually conspicuously longer and stouter in *rathbuni* than in *longispinis,* is a moderately useful character for separating small as well as large specimens.

The scale count appears to be lower in *rathbuni,* and the caudal is approximately truncate, instead of moderately emarginate. However, these two characters are not of much practical value, because of the state of preservation of most specimens. The scales are missing in large areas or over the greater extent of the body in the large majority of the specimens examined and their number not ascertainable with precision (that is why so few specimens of these two species are entered in table 6). Also, the caudal is frayed in many of the specimens examined and its normal shape not definitely determinable.

Differences in proportional measurements between the two species may be gathered by comparing their accounts giving measurements of five specimens of each in about the same size range. The greatest divergence is shown by the body depth and this measurement is further analyzed in table 10.

Small specimens do not have their specific characters developed to a sufficient extent to be distinguished as readily as large specimens. The most striking distinguishing character, the relative length of the third dorsal spine, does not develop until the fish reach a length of about 100 mm., more or less. The distinguishing specific characters are even less marked in specimens under 50 mm. The latter specimens are distinguishable by the presence of a dusky smudge on the pectoral of *rathbuni,* and the shape of the tentacle at the supraocular spine which is usually longer and broader in *rathbuni.* The anterior spinous point on the suborbital ridge develops at a somewhat smaller size in *rathbuni.* When placed side by side small specimens of *rathbuni* appear deeper-bodied, although this difference does not show well in measurements.

PONTINUS CASTOR Poey

Pontinus castor Poey, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 173, July 1860 (Cuba).

Sebastes nematophthalmus Gunther, Catalogue of fishes in the British Museum, vol. 2, p. 99, 1860 (West Indies, see discussion below; Gray's preface dated June 1, 1860, and volume very likely published after July).

Pontinus microlepis Bean, Proc. Biol. Soc. Washington, vol. 25, p. 125, 1912 (Bermuda).

D.XII 10. A.III 5. P.17. Sc.50-54. GR.7-8+14-15.

Description.—Eye about two-thirds as long as snout. Interorbital about one-third the eye diameter. Maxillary ending approximately under posterior margin of pupil. Nasal spine small; upper posttemporal spine small or absent; preorbital spinous points poorly developed, the anterior one blunt or very slightly projecting; suborbital ridge with 3 stubby spinous points. Supplemental preopercular spine a blunt projection (absent on one side in one specimen); second preopercular spine absent, fifth slightly developed or virtually absent at the surface. A variably long, slender tentacle at base of supraocular spine (absent on one side in two specimens, very long, about reaching dorsal origin on one side in one of these specimens) ; shorter, broader tentacles at preocular spine and lower preopercular spines present or absent. Scales on cheek, chest, anterior part of pectoral base, and interorbital mostly cycloid; snout and interorbital with small isolated groups of small cycloid scales, naked for their greater part. Fourth dorsal spine longest, thence gradually decreasing to penultimate, or fourth to sixth subequal; penultimate spine about three-fourths as long as last; longest dorsal spine a little shorter than snout and considerably shorter than postorbital part of head. Second anal spine moderately longer than third. (Caudal more or less damaged in the specimens examined, form of its posterior margin not definitely determinable.) Uniformly yellowish all over without color marks in preserved specimens.

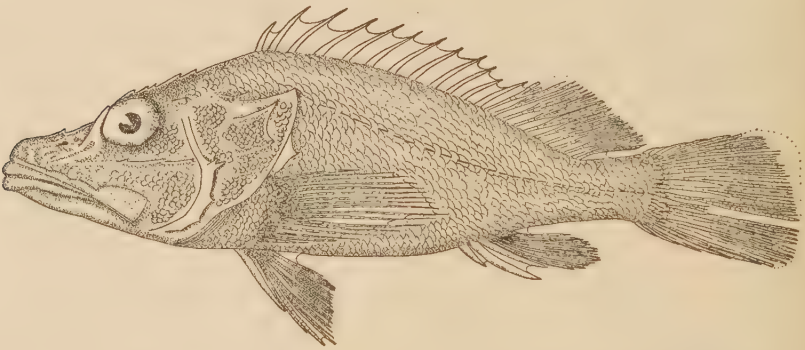

Fig. 5.—*Pontinus castor,* 228 mm., U.S.N.M. No. 74113, the holotype of *P. microlepis,* off Bermuda. Drawn by Mildred H. Carrington.

The above description is drawn from 3 specimens 171-228 mm. in the U. S. National Museum. One specimen examined in the Chicago Natural History Museum, 324 mm., but not directly compared, has the eye relatively smaller in relation to the snout and interorbital and the suborbital ridge is nearly smooth, having one slightly raised tubercle-like projection.

Measurements of 1 specimen 324 mm. and 3 specimens 171-228 mm.: caudal about 24.5 (23.5-26.5), ventral 22.5 (24.5-25.0), pectoral 26.5 (29.0-31.5), depth 34 (31.5-34.0), head 51 (48-49), maxillary 23 (22.5-23.0), snout 17.2 (16.0-16.5), eye 9.7 (10.4-11.3), interorbital 4.2 (3.4-4.0) ; eye 1.8 (1.4-1.6) times in snout, interorbital 2.3 (2.7-3.1) times in eye.

Specimens examined.—Cuba (29554, 37566; transmitted by Poey). Bermuda (74113, holotype of *microlepis,* fig. 5; C.N.H.M. 48526, 324 mm.). Total examined, 4 specimens 171-324 mm. The specimen listed last was taken at 90 fathoms; no depth records are available for the others.

Comparison.—In general appearance *castor* differs markedly, by its long snout, from its three congeners here treated. It further differs from those three species in having 10 dorsal spines, instead of a normal count of 9, and a greater number of scales. The second preopercular spine is absent, while in the other three species it is present, except in individual variants of *longispinis.*

Nomenclature and synonymy.—Two of the three specimens examined in the National Museum were received from Poey and are entered in the catalog as *castor.* Consequently, the present identification of *castor* is evidently appropriate. The type of *microlepis* belongs to the same species and its data are included in this account.

Gunther's *S. nematophthalmus* is possibly a composite species. Two specimens are listed: a stuffed specimen, size not stated, the locality of which is given as Île de France with a question mark, and one specimen 6 inches 7 lines, about 167 mm., from the West Indies. The given description apparently refers to the latter specimen, in large part at least. As the two specimens might belong to two species, the name *S. nematophthalmus* is formally restricted to the West Indies specimen which is hereby designated as the lectotype. Gunther's description, as far as it goes, fairly agrees in general with the specimens of *castor* examined and *nematophthalmus* is very likely based on a specimen of this species. Judged by the description, the body depth of Gunther's specimen appears to be somewhat greater and the head moderately shorter than in the four specimens examined, but the differences do not appear to be significant and might be accounted for by differences in method. Besides, Gunther does not give the standard and caudal length of his specimen, and the above comparison of measurements is made by assuming that its caudal is 25 percent of the standard length. These differences may not hold when the standard length of Gunther's specimen is actually determined and the same methods of measurements are used as in this investigation.

Genus NEOMERINTHE Fowler

Neomerinthe Fowler, Proc. Acad. Nat. Sci. Philadelphia, vol. 87, p. 41, 1935 (genotype *Neomerinthe hemingwayi* Fowler = *Pontinus pollux* Poey by original designation).

Definition.—Eye smaller than snout. Interorbital one-third to two-thirds the eye, depending on the species. Maxillary reaching approximately to under middle of eye. Palatine teeth present. A small slit behind last gill arch. Gill rakers moderate at angle; upper limb with 2-5 end gill rakers short, tubercle-like but individually readily distinguishable and countable; lower limb with 1-5 tubercles at end, some of them only slightly raised above surface of arch or much expanded lengthwise along arch, sometimes difficult to distinguish individually. Combined number of gill rakers and tubercles 6-7+9-12. Occipital region flat, without a pit. Parietal ridge divided into two subequal parts, each part ending in a spine; frontal spine directly behind postocular, the two placed on a line distinctly laterad of parietal ridge; upper posttemporal spine small or absent, lower posttemporal spine and ridge well developed; sphenotic spine very small, placed close to orbital rim; pterotic spine and ridge well developed; an extra ridge between frontal and sphenotic spines, and one or two ridges below parietal ridge not as well developed; postorbital spine absent; preorbital with 2 free spinous points, the posterior spine larger, broader and directed backward; suborbital ridge well developed with 3-5 spinous points (ridge becoming serrate in large specimens of *pollux;* see under its account); cleithral spine present. First preopercular spine longest, moderate in size but sharp, with a supplemental spine; second spine usually absent, when present in individual variants small in size. A rather broad tentacle at base of posterior preorbital spine, very variable in form, digitated or fimbriated, often divided into two or three main stems; smaller tentacles variably present at other spines on head; a fimbriated or entire tentacle at anterior nostril; no other tentacles. Scales ctenoid, except on pectoral base and chest ctenoid or cycloid; opercle and cheek almost all scaled; interopercle and maxillary partly scaled; interorbital and snout with or without scales. Dorsal typically with 12 spines; with 9 or 10 rays, depending on the species; penultimate spine about two-thirds to three-quarters as long as last. Second anal spine longer than third. Ventral reaching anus or falling short, its outer angle a little in front of lower pectoral angle. Pectoral irregularly wedge-shaped, the middle rays longest; with 5-8 branched rays; total number of rays constantly 17 in specimens examined. Caudal moderately rounded.

Comparison.—This genus agrees with *Scorpaena* in having palatine teeth, branched pectoral rays, the first preopercular spine longest, and 12 dorsal spines. It differs in having ctenoid scales; in the greater extent of scalation, the shape of the pectoral, and the position of the ventral. In the structure of the scales and their extent it about agrees with *Trachyscorpia,* and is compared with the latter under its account. It further differs from *Scorpaena, Trachyscorpia, Helicolenus,* and *Sebastes* in having a small and well-defined slit behind the last gill arch. On the whole, *Neomerinthe* is nearest *Pontinus.* The shape of the preopercle and its spinous armature is about the same in both genera. The second preopercular spine is small or absent in both. The two western Atlantic species with a prolonged third dorsal spine belong, one each, to these two genera, *Neomerinthe beanorum* and *Pontinus longispinis.* The pectoral shape and its number of rays and the nature and extent of scalation are nearly the same in both genera. They differ chiefly in that some of the pectoral rays are branched in *Neomerinthe* and all are unbranched in *Pontinus.*

NEOMERINTHE POLLUX (Poey)

Pontinus pollux Poey, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 174, 1860 (Cuba).

Neomerinthe hemingwayi Fowler, Proc. Acad. Nat. Sci. Philadelphia, vol. 87, p. 41, fig., 1935 (about 70 miles southeast of Cape May, N. J.; deep water).

Neomerinthe tortugae Hildebrand, Carnegie Inst. Washington Publ. 517, p. 247, fig. 13, 1940 (Tortugas, Fla.).

D.XII 10. A.III 5. P.17. Sc.62-68. GR.6-7+9-12.

Description.—Snout long and eye comparatively small, eye about three-quarters the snout length in medium-sized specimens, about one-half the length in large fish. Interorbital rather wide, about two-thirds the eye diameter in the larger specimens. Upper posttemporal spine absent, except in the young (see below); suborbital spinous points usually 4, sometimes 3 or 5; in large specimens (3 specimens 420-465 mm.) suborbital spines becoming greatly reduced in size and the ridge becoming serrate, the gross effect being a moderately serrate ridge, the serration somewhat interrupted; cleithral spine comparatively sharp. Second preopercular spine absent except in the young; third and fourth spines rather broad, the third somewhat larger, fifth spine virtually absent at surface. Most scales on chest and pectoral base ctenoid, rather weakly so; area on occiput limited by posterior part of parietal ridge and frontal spine with very small ctenoid scales, similar scales extending on interorbital, snout, anterior part of cheek, and partly on maxillary and premaxillary (small scales often absent in irregular patches in preserved specimens, probably deciduous); interopercle partly scaled. Penultimate dorsal spine about two-thirds as long as last spine; longest dorsal spine subequal to snout, shorter than postorbital part of head. Ventral about reaching anus in the smaller specimens, falling considerably short in large fish. Pectoral falling more or less short of a vertical through base of first anal spine;

uppermost 1 or 2 rays unbranched, next 6-7 rays branched, lower 8-9 unbranched.

Measurements of 3 specimens 250-420 mm., including the holotypes of *hemingwayi* and *tortugae,* and 2 specimens 136-152 mm.: caudal 23.5-24.5 (25.5), ventral 21.5-24.0 (26.0-26.5), pectoral 23.5-26.0 (28.0-28.5), depth 29.5-31.0 (34), head 45-46 (44-45), maxillary 20.5-21.5 (in all 5), snout 13.7-16.0 (13.2-14.8), eye 7.7-9.0 (10.3-10.8), interorbital 5.3-5.7 (5.6-5.9), eye 1.6-1.9 (1.3-1.4) in snout, interorbital 1.5-1.6 (1.8-1.9) in eye.

Ground color straw yellow to brownish with a somewhat reddish tinge; irregularly marked with large diffuse blotches and small spots; 1 blotch above and in juxtaposition to the lateral line under base of sixth to eighth dorsal spines, 1 or 2 blotches behind it but placed below lateral line and touching it; a series of diffuse smaller blotches at dorsal base; a somewhat curved bar directly in front of dorsal; small dark spots irregularly and variably scattered on body, head and fins including underside of pectoral and its fleshy base, except ventral plain yellowish. Intensity of markings described variable, often faint, sometimes hardly perceptible.

Development.—A small specimen, 53 mm., has the pectoral rays unbranched (some of the rays damaged), and it shows slightly the second preopercular and upper posttemporal spines.

Specimens examined.—Off the following localities: about 70 miles southeast of Cape May, N. J. (A.N.S.P. 63482, holotype of *hemingwayi,* 322 mm.). Cape Lookout, N. C. (152084). Bull Island, S. C. (151884). Tortugas (108871 and 108872, the holotype and 2 paratypes, respectively, of *tortugae*), Cape San Blas (144575, *Albatross;* 155336, *Pelican;* C.N.H.M. 46218, *Oregon*), St. Joseph Point (157557, *Oregon*), and Santa Rosa Island (157558, *Oregon*), Fla. Mississippi Delta, La. (155334-5, *Pelican;* C.N.H.M. 46217, *Oregon*). Gulf of Mexico (125716, no definite locality). Total examined, 16 specimens 53-465 mm., the largest from off Bull Island. Available depth records for 10 of the 14 constituent samples range 26-112 fathoms. Evidently this species is not uncommon offshore.

The spinous part of the dorsal in the type specimen of *hemingwayi* is evidently abnormal, having the second and third spines missing. It has the stump of a spine on the midback placed over the supracleithral spine. After some interval, the rest of the spinous dorsal consists of 9 spines the relative lengths of which are about the same as in normal specimens of this species. The first of the normally formed spines is placed over the posterior upper corner of the opercle.

Although the interval on the midback between the stump and the first ully formed spine is partly scaled over with imbricated scales, it is vident from the positions and relative lengths of the spines that this condition is a malformation probably due to an injury earlier in life n which the second and third spines were lost. In other characters and color this specimen agrees with the normal specimens of this species. A similar abnormality in a specimen of *Scorpaena agassizi* is decribed under that species.

Comparison.—This species is readily distinguishable from the other western Atlantic scorpaenids by the combination of its fin ray, scale, and gill-raker counts and its other generic and specific characters. It is compared with its congener, *beanorum,* under the account of that species. It agrees with *Pontinus castor* in having 10 dorsal rays, and nearly agrees in the spinous armature of the preopercle and the rather long snout.

Nomenclature and synonymy.—The types of *Neomerinthe hemingwayi* and *N. tortugae* have been examined. They belong to the same species and the data derived from the types are included in this account.

The type of *Pontinus pollux* Poey does not seem to be in existence now. Judged by the circumstances and known facts, it seems reasonably safe to conclude that Poey's specimen also belonged to the species here treated. According to the findings here reported only two species normally have 10 dorsal rays, this species and *Pontinus castor,* and Poey gives this count in the original descriptions of his *P. castor* and *P. pollux.* That Poey used the same method of counting the rays as employed in this paper, that is, counting the last 2 approximated rays as one, is proved by the count of *P. castor* in which Poey's count agrees with that here determined for 4 fish that included 2 specimens which were presumably identified by him. The number of pectoral rays, 17, as determined for 14 specimens examined of this species also agrees with that given by Poey. Also, in his description of *P. pollux* Poey compares it largely with *P. castor* stating that it is very near that species in shape. This is significant. There really is a striking resemblance between our species and *P. castor* in the shape of the body, head, and snout, and any student having specimens of both species before him would naturally be led to compare them at length. Furthermore, Poey's description of the differences between *P. castor* and his *P. pollux* in the suborbital and preorbital spinous points agrees fairly well with that between this species and *P. castor.* There are some minor discrepancies. Poey fails to mention the dark or dusky spots or shadings shown by this species; but the color is highly variable, some specimens examined having very faint shadings. Also, according to his description Poey's *P. pollux* had a narrower interorbital than our specimens, and the maxillary did not extend so far backward. However, such discrepancies are found in other descriptions by Poey and they do not seem of much significance. All in all, the probability is high that the not uncommon species here described is the same as Poey's *P. pollux* and it is here designated accordingly.

NEOMERINTHE BEANORUM (Evermann and Marsh)

Pontinus beanorum Evermann and Marsh, Bull. U. S. Fish Comm., vol. 20, pt. 1, p. 279, fig. 85 (1899) 1902 (San Juan Harbor, Puerto Rico).

D.XII 9. A.III 5. P.17. Sc.41-46. GR.6+9-10.

Description.—Eye moderately smaller than snout. Interorbital rather narrow, one-third the eye diameter or slightly wider. Upper posttemporal spine very small; ridge between frontal and sphenotic spines well developed, projecting, forming with side of head an inverted troughlike recess; a similar and smaller trough directly below parietal ridge; suborbital spines 3 or 4; cleithral spinous projection rather short and blunt. Second preopercular spine usually absent or a slight trace present, sometimes fairly shown; lower 3 spines narrow and sharp, the third directed downward and slightly backward or forward, fourth and fifth more or less antrorse. Most scales on chest and pectoral base cycloid; occipital area limited by posterior part of parietal ridge and frontal spine with scales of moderate size; maxillary and interopercle with very few scales or none; interorbital and snout scaleless. Third dorsal spine in male prolonged, rising above normal distal outline of fin; subequal to postorbital part of head in male, to snout in female; penultimate dorsal spine about three-quarters as long as last spine. Ventral falling moderately short of anus. Pectoral about reaching a vertical through base of first anal spine; its upper 2 rays unbranched, next 5-8 rays branched, lower 7-10 rays unbranched.

Measurements of 6 specimens 118-163 mm.: caudal 27.0-30.5, ventral 22.5-24.5, pectoral 29.0-30.5, depth 29.0-32.5, head 44-47, maxillary 21.5-22.0, snout 13.7-14.6, eye 11.4-12.8, interorbital 3.9-4.5; eye 1.1-1.3 in snout, interorbital 2.6-3.1 in eye.

Ground color of preserved specimens reddish yellow or olivaceous, upper part of body and head shaded with dusky irregular areas; spinous dorsal with a lengthwise row of smoke-colored blotches placed on posterior interradial membranes; soft dorsal, upper part of caudal, and upper posterior part of pectoral with small, diffuse, dark spots.

Specimens examined.—San Juan Harbor, Puerto Rico, 91 fathoms, *Fish Hawk* (49534, the holotype); off Puerto Rico, 80-180 fathoms, *Caroline* Station 35 (117877). Total examined, 6 specimens 118-163 mm.

Comparison.—This species differs chiefly from *pollux,* its known western Atlantic congener, in having fewer scales and 9, instead of 10, dorsal rays. The gill rakers are fewer on the average. The scalation on the head is somewhat less extensive. The eye is larger, the snout shorter and the interorbital narrower than in *pollux.*

TRACHYSCORPIA, new genus

Genotype.—*Scorpaena cristulata* Goode and Bean.

Definition.—Eye subequal to snout or a little larger. Interorbital about half the eye or a little narrower. Maxillary ending under posterior margin of pupil or a little behind. Palatine teeth present. No slit behind fourth gill arch. Gill rakers short, those at ends of arch very short, tubercle-like but individually distinguishable and readily countable; in medium numbers, 5-6+13. Occipital region with a slight, broad depression, without a definite pit. Spines on head well developed; parietal ridge divided into two parts, both ending in a spine; frontal spine not alined with parietal ridge, nearly in a line with postocular spine; upper posttemporal spine absent, lower one rather well developed; sphenotic spine small, single, usually with 1 or a small group of spinules or asperities or slight tuberosities below it; pterotic ridge and spine well developed; postorbital in form of a slight tuberosity or a group of slight asperities or absent; preorbital with 2 free moderate points, sharp or rather blunt; suborbital ridge notably well developed, with 6-7 spinous points. First preopercular spine longest, with a supplemental spine; second spine subequal to or shorter than third, placed nearer to first spine; fifth spine slightly indicated or obsolescent. Tentacles and filaments sparsely developed. Scales ctenoid, 57-67; except those on chest, fleshy pectoral base, and interorbital weakly ctenoid or cycloid, partly embedded; on dorsal aspect scales extending to opposite postocular spine; posterior and smaller part of interorbital scaled, its anterior and greater portion partly scaled or nearly scaleless; opercle nearly all scaled; cheek largely scaled to a variable point opposite pupil, except narrow area directly above and below suborbital ridge scaleless; maxillary and interopercle scantily scaled or naked; snout virtually scaleless; fins moderately or well scaled on a variable proximal area, except spinous dorsal and ventral. Dorsal normally with 12 spines; with 8-9 rays (see also below, counts recorded in the literature for *echinata*); rather deeply emarginate, penultimate spine about one-half to two-thirds as long as last spine; longest dorsal spine subequal to snout or a little longer. Anal with 3 spines and 5 rays; second spine subequal to third or a little longer. Ventral falling considerably short of anus, its outer angle close to lower pectoral angle. Pectoral broad and rather short with 11-13 branched rays, or 20-24 altogether, about reaching a vertical through anus; upper rays, third to fifth or seventh rays subequal and longest, thence gradually decreasing in size; lower rays thickened and their ends free for a short distance. Caudal truncate or slightly rounded.

Comparison.—The two species, *cristulata* and *echinata,* comprising this genus form a group that differs markedly from the other species here placed in *Scorpaena* as follows. The scales are strongly ctenoid, the head is much more extensively scaled and the pectoral shape is different. The ventral is placed close to the pectoral, instead of at some distance behind it. Correlated with these differences, the gill raker, pectoral ray, and scale counts fall near the upper limits of the range of *Scorpaena.*

The two species agree with *Helicolenus* in having ctenoid scales and nearly agree in the extent of scalation on the head. They differ in having the first preopercular spine longest, in the position and length of the ventral, and the pectoral shape. The spinous armature on the head of *Helicolenus* is not as well developed, as it usually lacks the sphenotic and pterotic spines and the suborbital keel has only one weak spinous point or none.

Trachyscorpia agrees with *Neomerinthe* in having ctenoid scales and the extent of squamation, and the armature of the head in the two genera is not trenchantly different. It differs in the shape of the pectoral which also has more numerous rays, in the position of the ventral, and in lacking a slit behind the fourth gill arch.

On the whole, *Trachyscorpia* is perhaps nearest *Osorioia* Fowler (1938, p. 63), agreeing with it in having ctenoid scales and nearly agreeing in the pectoral shape and other characters. *Osorioia* differs in having a shallow occipital pit and in lacking scales on the head, occiput, chest, and pectoral base.

I am establishing this new scorpaenid genus with a measure of reluctance. Many scorpaenid genera have been proposed in scattered studies, and the task remains of correlating properly and determining the relationship between the proposed genera by a revision of the family on a world-wide basis. It would, therefore, seem imprudent to add still another generic name to the long list of genera that have been proposed in a number of papers and that still remain undigested.

Nevertheless, the two species studied form a related group that does not seem to fit in well with any of the genera that have been proposed so far, and no choice remains but to propose a distinct genus to include these two species.

TRACHYSCORPIA ECHINATA (Koehler)

Scorpaena echinata KOEHLER, Résultats scientifiques de la campagne du *Caudan* dans le Golfe de Gascogne, *in* Ann. Univ. Lyon, 1896, p. 478, pl. 27, figs. 4-6 (lat. 45° 57′ N., long. 6° 21′ W.; Bay of Biscay; 1,410 meters).—NORMAN, *Discovery* Reports, vol. 12, pt. 1, p. 32, 1935 ("southwest of Ireland and in the Bay of Biscay").

Scorpaena cristulata KOEHLER (not Goode and Bean), op. cit., p. 524 (states in footnote that *echinata* the same as *cristulata;* specimens apparently not compared).—HOLT and BYRNE, Fisheries of Ireland Scientific Investigations, 1906, No. 5, p. 20, pl. 2, 1908 (off southwest Ireland, 250-800 fathoms).

D.XII 8. A.III 5. P.20. Sc.60. GR.5+13.

Description.—Eye a little larger than snout. Interorbital width one-half the eye diameter. Occipital area enclosed by parietal ridges and frontal spines only slightly longer than wide; posterior part of parietal ridge somewhat better developed than anterior part; no spine or projection on posterior margin of cleithrum (in the large specimen examined). First preopercular spine moderate; next three spines rather short, the second more pointed than other two and nearer to first; fifth spine virtually absent at surface. A lengthwise row of short, slender filaments on upper part of eyeball; similar, still shorter filaments on upper part of head and opercle. Interorbital with a few scattered, largely nonimbricate scales, its greater part scaleless; maxillary and interopercle scaleless. Penultimate dorsal spine about three-fourths as long as last. Second anal spine a little longer than third. Ventral reaching about half the distance from its base to anal origin. Pectoral having its uppermost ray unbranched, next 13 rays branched, lower 6 rays unbranched.

Measurements of a specimen 433 mm.: caudal 22, ventral 15, pectoral 25.5, depth 32, head 43.5, maxillary 23.5, snout 10.6, eye 11.9, interorbital 5.8; snout 1.1 and interorbital 2 times in eye.

Ground color light yellowish, lower part somewhat lighter; upper part of head and body irregularly marked with dusky shades, a brown blotch between suborbital ridge and eye, placed under pupil, somewhat better marked than other shadings; a U-shaped mark at origin of spinous dorsal, at its base; spinous and soft dorsal with black or dusky blotches or areas on interradial membranes; other fins unpigmented.

Specimen examined.—Lat. 51° 46′ N., long. 12° 14′ W., off southwest coast of Ireland, 550 fathoms, 433 mm. (61663). The above account is based on this one specimen. Other measurements and counts compiled from the literature on *echinata* are given below.

Comparison.—In accounts of the eastern Atlantic population, cited in the above synonymy, which has been named *echinata* and is closely related to the western *cristulata,* Koehler, in a footnote, and Holt and Byrne synonymize these two names. Norman tentatively treats *echinata* as a distinct species, but expresses doubt as to its distinctness. However, these authors evidently arrived at their conclusions by comparing their specimens with the account of *cristulata* rather than by a direct comparison of specimens. The specimen in the National Museum from the coast of Ireland, which forms the basis of the above description, makes possible a direct comparison of specimens from the eastern and western Atlantic.

Measurements of eastern Atlantic specimens were published by Koehler, 1 specimen 172 mm.; Holt and Byrne, 5 specimens 255-504 mm.; Norman, 6 specimens 330-510 mm. These measurements reduced to a percentage basis to correspond with the method here adopted, and divided into two size groups, 2 specimens 172-255 mm. and 10 specimens 358-510 mm. (Norman gives only part of the measurements), are as follows: ventral 14.5-16.5 (16.5-19.5), pectoral 23.5-24.5 (21.5-22.5), depth 31.5-35.5 (30.5-31.5), head 41-46 (41.5-44.0), snout 8.9-10.5 (8.8-10.7), eye 8.9-10.5 (10.5-13.5), interorbital 4.7-5.7 (4.7).

Comparing the preceding measurements with those given below for two similar size groups of *cristulata,* the eastern Atlantic specimens have a shorter head and ventral, a smaller snout and eye, a narrower interorbital, and the body not as deep. The eastern Atlantic specimen in the National Museum agrees in general with the previously published measurements of *echinata* as given above.

The eastern Atlantic specimen described above shows two noteworthy differences as compared with the extant description of *echinata.* It has 8 dorsal rays, and 20 pectoral rays (counted on both sides); whereas the given ranges in the published accounts of western Atlantic specimens are 9-10 dorsal and 21-22 pectoral rays. However, a spread of 3 in the frequency distribution of the dorsal and pectoral rays occurs also in other species (see table 1), although the variants from the predominating number of dorsal rays are generally few. At any rate the presence of only 8 dorsal rays in the specimen examined does not exclude it from being an example of *echinata.*

An adequate picture of the variability of these two counts in *echinata* remains to be determined by a study of a satisfactory sample. Meanwhile, it may be confidently concluded that the eastern and western Atlantic populations differ considerably, at least on the average, in the pectoral count, 20-22 and 22-24, respectively.

Besides the variability in the number of dorsal rays as discussed above, Holt and Byrne in the 5 specimens tabulated by them record 3 as having 12 dorsal spines and 2 with 11 spines. Norman also records 11-12 dorsal spines. In view of the relative constancy of the number of dorsal spines in all species (table 1), this is a noteworthy variation. In all 13 specimens examined of the western Atlantic *cristulata* the dorsal count is constantly XII 9, except one which has 8 rays.

In the western Atlantic specimens, the slight nuchal depression, the area enclosed by the parietal ridges and frontal spine, is notably longer than wide, while in the eastern Atlantic specimen examined it is only moderately longer than wide. The European specimen also has one gill raker less than 13 American specimens examined, the gill-raker count being constant in the latter.

Considering all differences discussed above, especially the differences in proportional measurements and the number of pectoral rays, it may be concluded with assurance that the eastern and western Atlantic populations represent distinct species.

Holt and Byrne describe their specimens as being shaded or blotched with dark pigment, and this also holds for the specimen in the National Museum from the coast of Ireland. Specimens of *cristulata,* on the other hand, are nearly uniformly colored or moderately shaded, and the type of *echinata* is described as uniformly colored also. This color difference and the unusual variability in the number of dorsal spines and rays shown by the Irish specimens, as discussed above, point to the possibility that the Bay of Biscay and Ireland populations diverge to a degree which remains to be determined.

TRACHYSCORPIA CRISTULATA (Goode and Bean)

Scorpaena cristulata Goode and Bean, Oceanic ichthyology, p. 246, pl. 67, fig. 242, 1895 (off Georgia).

D.XII (8) 9. A.III 5. P.22-24. Sc.57-67. GR.6+13.

Description.—Eye subequal to snout in large specimens, moderately larger in medium-sized fish. Interorbital one-half to one-third the eye diameter. Occipital area limited by parietal ridges and frontal spines, notably longer than wide; usually anterior part of parietal ridge longer and lower than, and its spine not as well developed as that of posterior part; cleithrum with a rather well-developed spinous projection in the smaller specimens, becoming reduced in large specimens. First preopercular spine extending more than half the distance across opercle in the smaller specimens, becoming relatively shorter with growth; supplemental spine well developed; second spine subequal to third or slightly smaller, placed nearer to first spine; lower 3 spines moderately developed, somewhat graduated. Short, slender filaments sparsely developed on upper part of eyeball and at some of the spines on the head. Interorbital scaled anteriorly, scaleless in large part at its middle portion; maxillary scantily scaled; interopercle with a few scales at its upper end or altogether scaleless. Penultimate dorsal spine about two-thirds as long as last spine in the smaller specimens, about half as long in larger fish. Second anal spine subequal to third or a little longer. Ventral reaching a little more than half the distance from its base to anal origin. Pectoral about reaching a vertical through anus, its uppermost ray unbranched, next 11-14 rays branched, lower 8-10 unbranched. In a large specimen, 400 mm., ventral reaching less than half the distance to anal origin, and pectoral falling a little short of a vertical through anus.

Measurements of 2 specimens 319-400 mm., 5 specimens 165-212 mm., and 3 specimens 100-142 mm. The following measurements are given in 3 groups in same order: caudal 20.5-22.0, 23.5-25.5, 24.5-26.5; ventral 17.5-18.0, 20.5-22.5, 21.5-24.0; pectoral 25, 24-27, 24.5-25.5; depth 34-36, 34.5-36.0, 33.0-34.5; head 47.5-48.0, 46.5-49.5, 46.0-47.5; maxillary 23-24, 23.0-24.5, 22.5-24.0; snout 12.2-13.5, 12.0-12.4, 11.4-11.9; eye 12.6-12.9, 13.5-14.8, 14.9-16.0; interorbital 5.4-6.8, 4.8-6.7, 4.5-5.5. Snout 1.0, 1.1-1.2, 1.3-1.4 and interorbital 1.9-2.4, 2-3, 2.9-3.3 times in eye.

Yellowish or golden nearly uniform without color marks in the preserved specimens examined; one specimen having occiput, interorbital, and a narrow lengthwise area above suborbital ridge, dusky in contrast with rest of uniform lighter coloration; some specimens having a dark irregular area on inner side of opercle, showing through on outer side as a dusky area.

Specimens examined.—From off the following localities: Nantucket Island, Mass. (41° 49′ N., 65° 49′ 30″ W., 84474 and 143932); Cape Hatteras, N. C. (44644); Charleston, S. C. (130962); Cumberland Island, Ga. (39362, the type); Key West (72979), Tortugas (92058), and Cape San Blas (50547), Fla. Total examined, 13 specimens 100-400 mm., the last one listed the largest. The vertical range is 72-440 fathoms.

Comparison.—This species is easily distinguished from other western Atlantic scorpaenids by the characters given in the key. It is nearest *echinata* from the eastern Atlantic and the differences between them are discussed above. A noteworthy feature of this species is that in all 13 specimens examined the combined number of gill rakers and tubercles on the first arch is constantly 6+13.

Genus SCORPAENA Linnaeus

Scorpaena LINNAEUS, Systema naturae, vol. 1, p. 266, 1758 (genotype by later designation).—BLEEKER, Versl. Akad. Amsterdam, vol. 9, p. 295, 1876 (*Scorpaena porcus* Linnaeus designated as genotype).—JORDAN and GILBERT, U. S. Nat. Mus. Bull. 16, p. 678, 1882 (*porcus* designated as genotype).

Definition.—Relative size of eye varying widely with the species from considerably larger than snout in *agassizi* to considerably smaller than snout in extreme variants of *plumieri,* with varying gradations in between among the other species. Interorbital likewise differing widely with the species from subequal to eye in *plumieri* to one-third the eye in extreme variants of *calcarata* and *inermis.* Maxillary end differing from a point under posterior margin of pupil or slightly in advance to under posterior margin of eye. Palatine teeth present. No slit behind fourth gill arch. Gill rakers moderately developed at angle of arch; upper limb with 1-5 end gill rakers low, tubercle-like, but distinguishable individually and readily countable; lower limb with 1-5 tubercles anteriorly still lower, well or moderately projecting beyond surface of arch, rounded, nearly always fairly distinguishable and countable; combined number of gill rakers and tubercles 3-7+6-12 or 10-17 in total number. Occipital pit present except in *inermis* and *calcarata* (the only genus here treated having a pit); nasal spine moderate or rather well developed, except often low in *inermis;* parietal ridge divided into two parts, the anterior part somewhat longer in small specimens, the two parts about subequal in large fish except in *bergi,* both parts ending in spinous points; frontal spine present, except in the larger specimens of *grandicornis,* placed at anterior corner of occipital pit, nearly in a line with parietal ridge except in *inermis, calcarata,* and *microlepis;* lower posttemporal spine present; upper posttemporal spine present, except subject to individual variability in *brasiliensis* and *microlepis,* present or absent; sphenotic spine rather small, usually double or bifid, often single, sometimes in form of a group of spinules or asperities; pterotic ridge well developed, ending in a spinous point; postorbital moderately or slightly developed or absent, when present often in form of a group of spinules or asperities; preorbital with 2 free spinous points, except 3 points in *dispar, plumieri,* and *microlepis;* suborbital ridge very moderate to well developed, with 1-4 spinous points depending on the species and intraspecific variability, occasionally smooth in individual variants; cleithral spine present or absent. First preopercular spine longest, with a supplemental spine except in *inermis* and *calcarata;* the lower four spines moderate, sometimes the fifth hardly perceptible; second spine subequal to or shorter than third, sometimes virtually absent in individual variants of *calcarata;* upper outer angle of interopercle sometimes ending in a projecting blunt or sharp point. Development of tentacles differing with the species and varying greatly with the individual. Scales cycloid, 41-76, extending in front of dorsal to a transverse line through anterior parietal spine; chest and fleshy pectoral base scaled, the scales embedded in some species; flexible part of opercle on area between the two diverging spines scaled, anterior area on hard part of opercle between the two ridges naked, except for a few nonimbricate scales sometimes present in *plumieri;* a few scales near preopercular margin, in some species the scalation extending backward from preopercular margin to cover a substantial or greater part of opercle; a rather large, somewhat wedge-shaped patch of scales covering greater part of cheek posteriorly below suborbital ridge; area above ridge between eye and preopercular margin more or less scaled; scales at preopercular margin, on cheek, and behind eye well embedded in some species, hardly appreciable at the surface; nuchal pit, interorbital, snout, maxillary, interopercle, and mandible scaleless. Dorsal typically with 12 spines; modally with 9 rays, except 8 in *inermis;* total range 7-10; penultimate spine differing with the species, about seven-eighths to two-thirds as long as last. Outer ventral angle placed behind lower pectoral angle. Pectoral with 5-10 branched rays, except in small specimens, total number of rays 16-21; distal margin of its upper part, to about eighth ray, evenly and moderately rounded, thence the rays rapidly decreasing in length downward. Caudal slightly or moderately rounded.

Development.—Young fish differ from grown specimens in certain characters, some of them of importance in distinguishing the species and genera. The approximate size at which a given character changes from the juvenile to the adult condition is given under the separate accounts of the species. General statements of changes with growth in some taxonomic characters are discussed here.

In small specimens all pectoral rays are unbranched as in the adults of *Pontinus.* Ramification is a gradual process. The rays that are destined to become branched assume a finely grooved appearance in young fish, for a short distance at their tip, when examined with a moderate power of a binocular microscope. The end of the ray appears to have longitudinal, crowded, very fine, alternate grooves and ridges. At first only one or two rays split at their tip. The number of forked rays and the length of the branches increase gradually. Usually the second ray is the last one to begin branching.

The relative development of the occipital pit differs with age. For instance, in *plumieri* a fairly well-developed pit is typically present, and *calcarata* has a slight occipital depression instead of a pit. But in young *plumieri* the pit is virtually absent, while in young *calcarata* the depression is somewhat better developed than in the adult.

The number of free preorbital spinous points is a specific character, 3 in *plumieri, dispar,* and *microlepis,* 2 in the other species. In *plumieri* the middle spine does not appear until the fish has reached some size. (Small specimens of *dispar* and *microlepis* are not available to determine this development.)

In the young the anterior portion of the parietal ridge is somewhat longer than the posterior part; while in grown specimens, except in *bergi,* the two parts are subequal.

The fleshy appendages, tentacles, filaments, and tabs, are better developed, in general, in the young than in grown specimens.

The edge of the scales in small specimens has a soft tumescent excrescence which is particularly noticeable in *plumieri.* It gives the fish a peculiar pimply appearance that is striking, but of no apparent taxonomic importance.

Comparison.—This genus differs from other western Atlantic scorpaenid genera, except *Setarches,* in having the scales cycloid instead of ctenoid. It differs from *Setarches* in its larger scales, and in having the first preopercular spine distinctly longer than the second and third. *Setarches* lacks a number of spines on the head that are present in *Scorpaena.*

SCORPAENA INERMIS Cuvier and Valenciennes

Scorpaena inermis Cuvier and Valenciennes, Histoire naturelle des poissons, vol. 4, p. 311, 1829 (Martinique).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535, p. 162, 1941 (Tortugas, Fla.).

Scorpaena occipitalis Poey, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 171, 1860 (Cuba).

Scorpaena luckei Fowler, Proc. Acad. Nat. Sci. Philadelphia, vol. 93, p. 87, figs. 1, 2, 1941 (Tortugas, Fla.).

D.XII 7-9. A.III 5. P.19-21. Sc.44-49. GR.3-5+6-8.

Description.—Eye a little larger than snout or subequal to it. Interorbital about 2.5 times in eye or a little narrower. Maxillary ending under posterior margin of pupil, varying a little both ways. Occiput between parietal ridges nearly flat, only slightly depressed, occipital pit virtually absent. Spines and ridges on head rather low; nasal spine notably low, often a mere blunt protuberance; frontal spine placed slightly laterad of a line marking parietal ridge; preorbital with 2 very moderate spinous points, the posterior spine directed downward; suborbital ridge usually having 2 rather weak spines, under middle and a little behind eye, the anterior one often obsolescent, sometimes also posterior one; cleithrum without a spinous projection. First preopercular spine reaching about half the distance from its base to posterior margin of opercle, without a supplemental spine; second spine moderate or very short, subequal to or shorter than third. A moderate or rather well-developed tentacle at supraocular spine, sometimes slightly developed; other tentacles and tabs on head, body, and upper opaque part of eyeball rather numerous; those at the spines and along lateral line usually rather more prominent; a row of well-developed tentacles along line marking boundary between upper opaque and lower transparent part of eyeball; a curving row of rounded tabs at opercular margin usually present. Opercle largely scaleless; scales on chest partly embedded; scales on fleshy pectoral base and cheek embedded, hardly or not at all visible at surface. Penultimate dorsal spine about three-quarters as long as last spine; longest dorsal spine a little shorter than postorbital part of head. Second anal spine longer than third. Ventral about reaching anus and pectoral about reaching a vertical through base of third anal spine, both varying a little both ways; uppermost pectoral ray unbranched, next 5-6 rays branched, lower 12-15 rays unbranched.

Measurements of 5 specimens 71-89 mm. including the type of *luckei* and a cotype of *occipitalis* and 2 specimens 32-34 mm.: caudal 27-30 (30.5-31.0), ventral 24-26 (26.0-26.5), pectoral 33-36 (31.5-33.0), depth 33.5-40.0 (34.5-38.0), head 45.5-48.5 (49-50), maxillary 23.5-26.0 (25-26), snout 12.4-13.8 (12.7-13.4), eye 13.3-16.2 (16.3-17.8), interorbital 3.6-4.3 (5.3-5.8); snout 1.0-1.2 (1.2-1.4) and interorbital 2.6-4.4 (3.3) times in eye.

Opaque, usually whitish, rather narrow columns descending from the line marking the boundary between the upper opaque and the lower transparent parts of eye, the columns expanding in rounded areas at their lower ends, altogether producing effect of inverted mushroomlike figures on transparent part of eye (these marks often few or undeveloped in specimens 55 mm. or less). Upper and greater part of body irregularly mottled and shaded with brown against a lighter background, sometimes the pigment aggregated in places to give a faint suggestion of incomplete cross bands; ventral aspect light-colored or whitish. Many of the tentacles and tabs whitish. Caudal with two cross bands, one at its distal margin, the other at a moderate distance in front of it.

Development.—In 3 specimens 32-36 mm., all pectoral rays are unbranched. At 55 mm. the rays are branched virtually as in the adult.

Specimens examined.—Miami to Angelfish Creek (C.N.H.M. 46212), Florida Reefs just south of Biscayne Bay (C.N.H.M. 46213), and Tortugas (117135, fig. 6; A.N.S.P. 69716, type of *S. luckei*), Fla. Eleuthera Island, Bahamas (53212). Cuba (153576-7; cotypes of *S. occipitalis*). Ensenada de Santa Rosa (82553) and Ensenada de Cajón (82554), Cuba. Luispena Channel, Puerto Rico (117878). Curaçao (38595). The above-listed 11 lots comprise 18 specimens 32-89 mm., the largest one from Curaçao.

Comparison.—This species is nearest to *calcarata,* agreeing with it in the lack of a definite occipital pit, a supplemental preopercular spine, and other characters. The differences between them are indicated in the key and discussed under the account of *calcarata.*

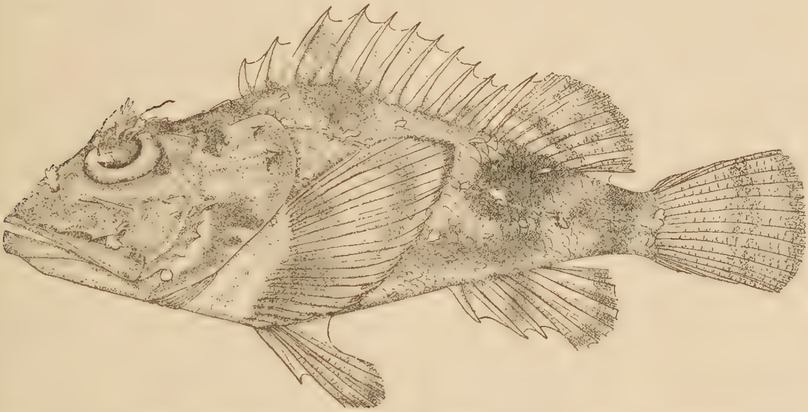

Fig. 6.—*Scorpaena inermis,* 82 mm., U.S.N.M. No. 117135; Tortugas, Fla. Drawn by Mildred H. Carrington.

Synonymy.—The type of *luckei* 67 mm. and 2 cotypes of *occipitalis* 46-71 mm. were examined and their data included in this account. All three specimens have 8 dorsal rays, the cross bands on the caudal are well developed, and they lack a spot behind the head. The type of *luckei* has the eyes dark, apparently caused by the preservative, but the inverted mushroom-shaped areas are discernible when viewed with a magnifying lens in the proper light. The 71-mm. cotype of *occipitalis* also has these areas. The three types also agree in other characters with the other specimens examined. They all belong to the same species which was identified by Longley with *inermis* after an examination of its type.

SCORPAENA CALCARATA Goode and Bean

Scorpaena calcarata Goode and Bean, Proc. U. S. Nat. Mus., vol. 5, p. 422, 1882 (Clearwater Harbor, Fla.).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535, p. 164, 1940 (Tortugas).

Scorpaena russula atlantica Nichols and Breder, Proc. Biol. Soc. Washington, vol. 37, p. 21, pl. 7, 1924 (off Galveston, Tex.).

Scorpaena mercatoris Delsman, Mem. Mus. Roy. Hist. Nat. Belg., ser. 2, fasc. 21, p. 74, fig. 11, 1941 (Cay Sal Bank).

D.(XI)XII(XIII) 8-9 (10). A.III(4) 5(6). P.(18) 19-21. Sc.41-49. GR.(3)4-5+7-11.

Description.—Eye larger than snout. Interorbital 2-3 times in eye. Maxillary ending under posterior margin of pupil or a little behind. Occiput between parietal ridges with a very shallow depression, somewhat better marked in small specimens, without a definite pit. Frontal spine placed a little laterad of a line through low parietal ridge; upper posttemporal spine very moderate or slight, sometimes a mere bony angle rather than a spine; parietal ridge and upper posttemporal and supracleithral spines often alined in a curved or nearly straight line; sphenotic armature in form of a group of spinules or blunt asperities, 1-4 in number; preorbital with 2 free moderate spinous points, posterior spine usually directed downward or slightly forward (this spine doubled in one specimen observed); suborbital ridge usually with 2 moderate or slight spinous points, one under eye and one at posterior end of ridge, sometimes anterior one, less often also posterior one, absent or hardly perceptible, occasionally a third slight projection between the two usual points; cleithrum without a spine. First preopercular spine rather long, usually reaching more than half the distance from its base to opercular margin, without a supplemental spine; second spine notably small, smaller than third, occasionally absent; fifth spine usually in form of broad, blunt projection, sometimes minutely serrate; preopercular margin above first spine usually with sparse, slight, variable, and irregular serrations, sometimes with 1 or 2 comparatively prominent points. A small tentacle at base of supraocular spine sometimes present, usually absent (well developed in small specimens); a row of tentacles on eyeball marking boundary between upper opaque part and lower transparent part; some small elongate tabs along edge of preopercle often present; some broad, fimbriated tentacles often present along course of lateral line; smaller tentacles on head, body, and eyeball variable, few to many. Opercle largely scaleless; scales on chest, fleshy pectoral base, opercle, and cheek more or less embedded or fairly distinguishable at surface. Penultimate dorsal spine about two-thirds as long as last spine; longest dorsal spine shorter than postorbital part of head. Second anal spine subequal to third varying a little both ways. Ventral reaching anus or a little behind. Pectoral about reaching a vertical through base of third anal spine, varying a little both ways; its uppermost ray unbranched, next 5-7 rays branched, lower 12-14 unbranched.

Measurements of 4 specimens 108-159 mm., 3 specimens 65-75 mm., and 2 specimens 31-36 mm., all from the coast of the United States, given in 3 groups in the same order: caudal 29-32, 30-31, 32.5-33.5; ventral 22.5-25.5, 25.5-27.5, 25.0-26.5; pectoral 32.5-35.5, 34.0-36.5, 33-37; depth 32.5-35.0, 35.0-37.5, 39.5-40.0; head 42.0-45.5, 44.0-44.5, 49.0-49.5; maxillary 21.5-23.5, 22-23, 25.5-26.5; snout 11.2-12.1, 10.9-11.8, 11.3-13.3; eye 12.4-15.3, 14.0-16.5, 17.2-17.8; interorbital 5.1-5.8, 5.5-6.5, 6.7-7.6. Snout 1.1-1.3, 1.2-1.5, 1.3-1.5 and interorbital 2.1-3.0, 2.3-2.6, 2.3-2.7 times in eye. (See also below, measurements of 2 Caribbean specimens.)

Short, elongate, oblong or broad, opaque, whitish areas extending on transparent part of eye at base of some of the tentacles in the horizontal row on the eyeball present or more often absent; when present not mushroom-shaped as in *inermis*. Upper part irregularly shaded, sometimes dusky, shading somewhat more marked in 4 transverse areas, giving very faint suggestion of a cross-banded pattern; a dusky blot a little behind head, at and below lateral line, faintly or moderately marked in most specimens, sometimes imperceptible; first dorsal often with 2 lengthwise rows of diffuse spots; second dorsal sometimes with oblique rows of diffuse smaller spots; caudal usually uniformly light-colored, sometimes with 2 transverse, rather faintly shaded cross areas near its middle and at its margin; ventral in the smaller specimens usually dusky to nearly black distally; body and fins often mottled with whitish, especially in the smaller specimens.

Development.—The pectoral rays begin to branch in fish between 35 and 40 mm. The nuchal depression is relatively better marked in small fish which also have a well-developed tentacle at the supraocular spine.

Specimens examined.—This is not an uncommon offshore species on the east coast of the United States whence 167 specimens 22-159 mm., in 69 constituent samples, were examined, ranging from off the mouth of Chesapeake Bay (102177) to Tortugas, Fla., to off Padre Island, Tex. (155310), including the type of *calcarata* (23556, Clearwater, Fla.) and the holotype of *russula atlantica* (86167, off Galveston, Tex.). Also, 4 specimens 94-145 mm. from off Cabo Catoche (101602, 148349) and 25 specimens 96-130 mm. from off Campeche (157543-4), Yucatan Peninsula; 1 specimen 68 mm., Flanagan Passage, Virgin

Islands (47642); 1 specimen 75 mm., off the Caribbean coast of Colombia (142881). The largest specimen, 159 mm., is from off South Carolina (151941). Depth records are available for most lots examined and range 7-50 fathoms.

Comparison.—This species is very close to *inermis* and the name *calcarata* had been placed in the synonymy of that species until Longley determined some of their differences. Other distinguishing characters have been elaborated during this investigation. The main differences between them are stated in the key, and they are not absolute. Besides these differences, *calcarata* usually has the upper posttemporal spine placed slightly higher up, almost directly behind the parietal ridge, the second preopercular spine is generally somewhat smaller, sometimes absent, and the nasal spine is somewhat better developed. The two species probably also differ in the averages of some proportional measurements, as may be gathered by comparing their accounts. While the two species do not differ sharply in any one character, they are satisfactorily distinguishable when all their differences are taken into consideration.

From the other species of its genus here treated, *calcarata* differs in lacking a supplemental preopercular spine and in the virtual absence of an occipital pit. Among those species it seems to be nearest to *agassizi,* with which it is compared below.

Populations.—The two Caribbean specimens examined are those entered in table 4 as having 41 rows of scales, while those from the coast of the United States and the Yucatan Peninsula have 42-49 scales. The measurements of these two specimens, 68-75 mm., are: caudal 30.5, ventral 23.5-24.0, pectoral 31, depth 37.5-38.5, head 44.5-47.0, maxillary 23-24, snout 10.6-10.7, eye 17.0-17.3, interorbital 4.6-5.0; snout 1.6 and interorbital 3.4-3.8 times in eye. Comparing these with the measurements of three specimens of similar size from the coast of the United States, given above, the tropical American specimens average a shorter ventral and pectoral, a deeper body, a longer head and maxillary, a shorter snout, a larger eye, and a narrower interorbital. While the precise extent of divergence of the tropical American population is, of course, indeterminable from only two specimens, it appears to be no greater than that of racial magnitude.

The 29 specimens from off the Yucatan Peninsula more frequently have 8 dorsal rays and 21 pectoral rays, the frequency distributions being as follows. Yucatan Peninsula: dorsal rays 8 (in 7 specimens) or 9 (in 22); pectoral rays 19 (1), 20 (19), 21 (9). All other constituent samples combined: dorsal rays 8 (16), 9 (159), 10 (3);

pectoral rays 18 (1), 19 (22), 20 (133), 21 (20). Approximately one-fourth of the Yucatan specimens have 8 dorsal rays and one-third have 21 pectoral rays.

Synonymy.—The holotype and paratype of *S. russula atlantica* have been examined and their data included in this account. Longley previously placed *atlantica* in the synonymy of *calcarata.*

The name *mercatoris* is here doubtfully placed in the synonymy of *calcarata,* as Delsman's brief description does not admit a positive identification of his specimen without its reexamination. His account agrees with *calcarata* in the main, and no essential character is given to show that *mercatoris* is different. The eye of *mercatoris* is said to measure 4 times in the head, whereas in 11 specimens of *calcarata* measured the eye varies 2.6-3.4 times in the head; but this slight difference may readily be ascribed to a difference in method. The figure of *mercatoris* shows a notably long snout; but the drawing is obviously rather crude and no special significance can be attached to this seeming difference. It seems highly probable that *mercatoris* is based on a specimen of the common *calcarata.* Another possibility is that *mercatoris* is a synonym of *inermis.*

SCORPAENA AGASSIZI Goode and Bean

Scorpaena agassizi Goode and Bean, Oceanic ichthyology, p. 247, pl. 67, fig. 243, 1895 (*Blake* station CCLIX).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535, p. 159, 1941 (Tortugas).

D.XII (XIII) (8) 9. A.III (4) 5. P.19-21. Sc.43-53. GR.4-6+8-11.

Description.—Eye notably large, snout about two-thirds as long as eye. Interorbital about one-half the eye diameter. Maxillary ending under space between posterior margin of pupil and that of eye. Occipital pit moderate. Spines on head well developed; sphenotic usually bifid, sometimes single, sometimes 2 very blunt projections directly below sphenotic; preorbital with 2 spines, the posterior one usually notably long, directed backward, almost horizontal; suborbital ridge usually with 3 well-developed spines, the anterior one more widely spaced than posterior two, sometimes one or two of the spines hardly perceptible, sometimes a fourth small spine present in front; cleithrum without a spine. First preopercular spine moderate, reaching about half the distance from its base to opercular margin, with a supplemental spine; second spine smaller than third. Tentacle at supraocular spine short or absent; other tentacles or filaments usually rather sparse. Chest in the smaller specimens normally scaled and with a smooth surface, with growth becoming much wrinkled in a somewhat cerebriform manner, without scales visible at the surface, with some deeply embedded, nonimbricate scales; scales on fleshy pectoral base and head partly embedded; opercle largely scaleless. Penultimate dorsal spine about three-quarters as long as last spine; longest dorsal spine subequal to postorbital part of head or very slightly shorter. Second anal spine subequal to or a little shorter than third. Ventral reaching anus or anal origin. Pectoral reaching a vertical approximately through end of anal base, varying a little both ways; its uppermost ray unbranched, next 6-8 rays branched, lower 11-13 unbranched.

Measurements of 5 specimens 116-172 mm. and 2 specimens 31-36 mm.: caudal 33.5-37.0 (32-33), ventral 23.5-28.5 (27.5-28.0), pectoral 44.0-48.5 (34.5-35.0), depth 32.5-39.5 (42), head 43.5-47.5 (48.5-49.0), maxillary 20.5-23.5 (24-25), snout 9.7-11.7 (9.3-11.6), eye 15.5-17.0 (17.3-20.3), interorbital 8.1-8.6 (9.4-10.5); snout 1.4-1.6 (1.5-2.2) and interorbital 1.9-2.0 (1.8-2.0) times in eye.

Upper part of body and head lightly and irregularly pigmented with dusky shades, one specimen with a few small dark points on nape extending to the area over opercle and a little behind head; the dusky pigment somewhat more concentrated in a small area behind head, giving very faint suggestion of a dusky blot; in addition to the general distribution of pigment as described, the pigment also more concentrated over central and greater part of area of each scale, surrounded by a lighter peripheral margin; distal edge of pectoral and ventral with a dark margin present or absent; the fish, including fins, otherwise notably light-colored. The above description drawn from three specimens after 2 years in preservative (152042). Specimens kept longer in preservative plain yellowish or grayish without distinctive markings; tabs sometimes whitish. Young specimens having distal part of ventral and often also that of pectoral dusky or blackish; soft dorsal and anal with dusky pigment separated by a clear area near middle; specimens in one lot of young fish, after many years of preservation, being suffused or mottled with a bright pink color, in some of these specimens the pink color incompletely separated into four broad areas, giving a faint suggestion of a cross-banded pattern, the bands extending partly on dorsal fins.

Development.—The pectoral rays begin to branch between 50 and 55 mm. The occipital pit is developed about as in the adult in specimens as small as 30 mm. Small specimens have the tentacles better developed. The tentacle at the supraocular spine is notably well developed and fimbriated and other rather well-developed tentacles are distributed on the head and body, being especially conspicuous along the course of the lateral line, at its anterior part.

The appearance of the chest in the larger specimens of *agassizi* is unique among the western Atlantic scorpaenids. In the smaller specimens the chest has a normally even and scaled surface as in the other species. With growth the chest becomes notably wrinkled and assumes somewhat of a cerebriform appearance, while the scales become deeply embedded and nonimbricate.

An unusual variant.—One small specimen, 42 mm. in standard length, from Sand Key, Fla. (74093), not in good condition, fairly agrees in its characters with *agassizi;* but the dorsal fin has a peculiar structure. It has 2 spines united by membrane and detached from the rest of the fin by an intervening space of considerable extent. The posterior part of the dorsal consists of 8 spines and 9 rays. Although the midback in the intervening space is scaled over and the specimen seems normal, it agrees so nearly with *S. agassizi* that it is safe to assume that this peculiar structure is caused by an early injury involving two of the dorsal spines. The type of *Neomerinthe hemingwayi* Fowler shows a similar development (see p. 54).

Specimens examined.—From off the following localities. Mid-Atlantic: *Blake* station 259, lat. 23° 10′ N., long. 39° 10′ W. (153583; one specimen 148 mm. taken at same station as holotype, but not mentioned in original description). Coast of North Carolina (152042). Cape Lookout (101545) and Cape Fear (91430), N. C. Palm Beach (153219), Cape Florida (72980), Sand Key (74093), Key West (101600, 131612, 132197, 134160), Tortugas (117126-8, inclusive; 144570), Cape St. George (157548), Cape San Blas (133999, 157549), and Santa Rosa Island (157550), Fla. Total examined, 106 specimens 20-176 mm., the largest from off Cape St. George. Available depth records range 37-116 fathoms. This is evidently not an uncommon species offshore.

Comparison.—This species has the longest pectoral and largest eye of any species of *Scorpaena* here treated. *S. calcarata* approaches it in these two characters, and both are sometimes taken together in the same trawl drags. It differs from *calcarata* in having a supplemental preopercular spine and a fairly developed nuchal pit. The comparatively long posterior preorbital spine of *agassizi,* the structure of its chest, and its nearly plain color are diagnostic of most of the larger specimens.

SCORPAENA BRASILIENSIS Cuvier and Valenciennes

Scorpaena brasiliensis Cuvier and Valenciennes, Histoire naturelle des poissons, vol. 4, p. 305, 1829 (Brazil).

Scorpaena stearnsi Goode and Bean, Proc. U. S. Nat. Mus., vol. 5, p. 421, 1882 (Pensacola, Fla.).

Scorpaena colesi Nichols, Bull. Amer. Mus. Nat. Hist., vol. 33, p. 537, fig. 1, 1941 (Cape Lookout, N. C.).

Scorpaena isthmensis Beebe and Tee-Van (not Meek and Hildebrand, which is a synonym of *bergi*), Zoologica, vol. 10, No. 1, p. 188, fig., 1928 (Port au Prince, Haiti; specimen reexamined).

D.XII (XIII) (7-8) 9. A.III (4) 5 (6). P.(17) 18-20. Sc.50-62. GR.4-5+8-10.

Description.—Eye moderate, snout subequal to eye, varying a little both ways. Interorbital nearly one-half to about two-thirds the eye diameter. Maxillary ending under posterior margin of eye or slightly more forward. Occipital pit well developed. Upper posttemporal spine absent or small; preorbital spines 2, well developed, posterior one directed downward or nearly so; suborbital ridge usually with 3 moderate spinous projections, often one or two of them very slight or imperceptible; cleithrum with a slight spinous projection disappearing in large specimens. First preopercular spine extending about half the distance across opercle or a little more; supplemental spine very small or moderate, virtually absent in infrequent variants; second spine subequal to third or smaller; fifth spine rudimentary or absent. Tentacle at supraocular spine very variable, short to moderately long; other tentacles, tabs, or filaments on head, body, and eye also very variable from sparse to profuse. Opercle moderately scaled, anterior area above upper spine scaled, a variable patch of scales below lower spine; scales on fleshy pectoral base, chest, and head partly embedded. Penultimate dorsal spine about two-thirds as long as last spine; longest dorsal spine subequal to postorbital part of head in the smaller specimens, shorter in larger fish. Second anal spine more or less shorter than third. Ventral reaching anus or anal origin. Pectoral reaching a vertical through base of first to third anal spine; its first ray unbranched, the following 7-10 branched, the lower 8-11 unbranched.

Measurements of 6 specimens 118-293 mm. including the types of *stearnsi* and *colesi,* and 2 specimens 46-48 mm., all from the coast of the United States: caudal 30.5-35.5 (33-34), ventral 23-26 (26-28), pectoral 33.0-38.5 (32.5-34.0), depth 34.0-37.5 (40.0-40.5), head 41.0-43.5 (43.0-45.5), maxillary 20.0-22.5 (23.5), snout 10.8-12.1 (11.5-12.4), eye 10.5-12.4 (14.6-15.2), interorbital 5.8-7.7 (8.0-8.9);

snout 0.9-1.1 (1.2-1.3) and interorbital 1.6-2.1 (1.7-1.8) times in eye. The measurements of one specimen 135 mm. from Brazil fall within the above given ranges of variation.

Two rather large spots on a horizontal line through second opercular spine, the first directly behind head, the second at a moderate distance behind in juxtaposition to lateral line, the two spots usually sharply or moderately marked, sometimes rather faint; sometimes a spot over space between preceding two spots, sometimes a third faint spot in a row with and behind the two; lower part of body with many irregularly scattered small spots of variable intensity, extending to pectoral base and usually on anterior part of inner side of fin, number of such small spots very variable from profuse to nearly or quite absent; sometimes similar spots but averaging fewer in number, also on head, pectoral base, and upper part of body; sometimes two irregular, diffuse, incomplete cross bands on posterior part of body and caudal peduncle, rather faintly indicated; sometimes rather dark or marbled or suffused with a whitish shade in part or nearly all over; often with two or three very diffuse spots at dorsal base; oblique bands on dorsal and anal poorly marked; caudal with a broad brownish transverse band at its margin and one near its middle; two or three similar but less well-marked bands at base, margin, and middle of pectoral; sometimes body and fins almost uniformly light-colored or variably shaded.

Development.—The pectoral rays begin to branch when the fish reach approximately a length of 50-55 mm. The occipital pit is relatively shallow at 31 mm. and becomes about as deep as in the adult at 45 or 50 mm.

Specimens examined.—Atlantic coast of the United States, ranging from off Cape Henry, Va. (127411), to off Tortugas, Fla., including the type of *colesi* (A.M.N.H. 4689); 66 specimens in 44 constituent samples. Gulf coast of Florida, ranging from off Cape Sable to Pensacola, including the type of *stearnsi* (30169); 47 specimens in 28 constituent samples. One specimen obtained by the *Grampus* off Galveston, Tex. (148137, 95 mm.). Also, off or at the following localities: Cabo Catoche (91431, 144574; altogether 5 specimens 182-213 mm.) and Campeche (157546-7, 2 specimens 187-201 mm.), Yucatan Peninsula, Mexico. Jamaica (32084, 2 specimens 171-204 mm.). Port au Prince, Haiti (N.Y.Z.S. 7381, 211 mm.). St. Thomas, Virgin Islands (9325, 38651; 2 specimens 32-174 mm.). Rio de Janeiro (83177, 182 mm.) and Bahia (43276, 135 mm.), Brazil. Total examined in detail, 128 specimens 31-293 mm. Besides the above, 74 specimens 42-256 mm. in 28 constituent samples were rapidly examined in the Chicago Natural History Museum and the University of Michigan Museum of Zoology after the manuscript of this account was drawn up, to verify the conclusions arrived at. The largest specimen is from off Savannah (155324). Available depth records range 1-56 fathoms. This is evidently a fairly common offshore species obtained by trawling and is also taken inshore by seining. On the Gulf coast of the United States all specimens examined were collected on the west coast of Florida, except one small specimen from Texas. Gunter (1948, p. 159) also records only two small specimens from Texas of those examined by him. Apparently this species is rather common on the west coast of Florida and comparatively uncommon on the northern Gulf coast westward of Florida.

Comparison.—This species is distinguishable from its western Atlantic congeners by its relatively high scale count and its distinctive color pattern, especially the presence of two dark spots behind the head and the small black spots in the pectoral axil, although the divergence is not pronounced. The lower extreme of its scale-count distribution approaches the other species closely and overlaps with *agassizi,* and the distinctive color pattern is not evident in all specimens. The absence or small size of the upper posttemporal is of some help in distinguishing *brasiliensis,* as well as the frequency distribution of its pectoral and gill-raker counts, its proportional measurements, and the relative length of the second and third anal spines. On the whole, it is not a difficult species to distinguish.

Synonymy.—The types of both *stearnsi* and *colesi* which are here placed in the synonymy of *brasiliensis* have been examined and their data included in this account of the species. The name *stearnsi* generally and correctly has been placed by authors in the synonymy of *brasiliensis.*

Nichols, in describing his *colesi,* compares its type with *brasiliensis* and points out some differences. However, an examination of a rather large composite sample of *brasiliensis* proves that these differences have their basis in intraspecific individual variability. The structural characters of the type of *colesi* easily fall within this range of variability. Nichols in his account of *colesi* describes the three or two large lateral blotches and the small dark axillary spots that are characteristic of *brasiliensis.* These color marks are now largely faded, but their traces may still be discerned.

SCORPAENA GRANDICORNIS Cuvier and Valenciennes

Scorpaena grandicornis CUVIER and VALENCIENNES, Histoire naturelle des poissons, vol. 4, p. 309, 1829 (Martinique; Puerto Rico).—JORDAN and EVERMANN, U. S. Nat. Mus. Bull. 47, p. 1850, pl. 273, fig. 672, 1898 ("Florida Keys to Brazil").

D.XII (XIII) (8) 9 (10). A.III (4) 5. P.17-19. Sc.44-49. GR.4-6(7) + (7)8-10.

Description.—Eye slightly or moderately larger than snout. Interorbital about two-thirds eye diameter. Maxillary ending under posterior margin of pupil or a little behind. Occipital pit notably well developed. Spines on dorsal aspect of head notably well developed, their bases broad, somewhat shelflike; frontal spine absent in the larger specimens, very moderate or small in small specimens; upper posttemporal subequal to lower; preorbital with 2 free spinous points, the anterior one very moderate; spines on suborbital ridge very variable, 1-3, sometimes none, the one at end of ridge usually present, sometimes absent; cleithrum with a moderate spinous point in the smaller specimens tending to disappear with growth. First preopercular spine extending less than half the distance across opercle; second spine subequal to third or longer; fourth and fifth spines very slightly developed or imperceptible. Tentacle at supraocular spine notably well developed, long, broad, and branched or fimbriated, usually reaching dorsal origin; other well-developed tentacles along course of lateral line, on head and eyeball; smaller tentacles or tabs irregularly scattered on body and head. Opercle moderately scaled, anterior area over upper ridge scaled, a variable patch of scales below lower ridge at preopercular margin and sometimes a few scattered, nonimbricate scales on rest of opercular extent below lower ridge. Penultimate dorsal spine four-fifths to nine-tenths as long as last spine; longest dorsal spine subequal to postorbital part of head in the smaller specimens, moderately shorter in large fish. Second anal spine longer than third. In the larger specimens ventral reaching to anus, and pectoral over base of first anal spine or shorter; in the smaller specimens ventral about reaching anal origin and pectoral to over base of first to third anal spine; pectoral having the first ray unbranched, the following 7-9 branched, the lower 7-10 unbranched.

Measurements of 5 specimens 113-181 mm. and 2 specimens 32-47 mm., from Key West, Cuba, Puerto Rico, Guadalupe Island, Panama, and Brazil: caudal 29.0-33.5 (34.5), ventral 25.5-29.5 (27.5-28.5), pectoral 33.5-37.0 (33), depth 40.5-42.5 (43.5-45.0), head 41-43 (44.5-45.5), maxillary 19.5-20.5 (22.5), snout 9.8-10.7 (11.2-12.1), eye 10.7-12.2 (14.6-15.1), interorbital 6.8-8.3 (7.9-8.4); snout 1.0-1.2 (1.2-1.3) and interorbital 1.5-1.7 (1.8-1.9) times in eye.

An area at upper pectoral angle, extending partly on the side of the body and partly on inner surface of fin, with many very small, crowded, whitish, rounded spots, often ringed with dark pigment. Strongly pigmented with dark color on head, body, and fins; often prevailingly dark all over except ventral aspect; often with 2 broad, dark cross areas on posterior lower part of body, one under soft dorsal, the other on caudal peduncle, abruptly separated by a lighter area; caudal with 2 broad cross bands, at its middle and at the margin; soft dorsal, anal, and pectoral usually with oblique or transverse, more or less irregular, lighter areas separating the dark color; ventral often nearly black distally, lighter proximally; sometimes with a transverse black area at some distance from its end; head and body with many very small white dots, similar to dots in pectoral axil but smaller, usually well marked in the lighter-colored specimens, imperceptible in dark fish.

Development.—The pectoral rays begin to branch at about 60 mm. The occipital pit is well developed in the smallest specimen examined, 32 mm.

The frontal spine is very small in young fish and disappears with growth, the size at disappearance varying greatly with the individual. The smallest specimen examined lacking the frontal spine is 59 mm., and the largest having it is 110 mm. Nine specimens 32-58 mm. all have a small frontal spine; 23 specimens 113-181 mm. lack this spine; of 35 specimens 59-110 mm., 15 have the spine, at least a trace of it, some of them on one side only, and 20 lack it.

Specimens examined.—Key West (35101, 67655), Boca Chica (148130), and Tortugas (117139), Fla. Castle Harbor, Bermuda (50949). Cuba (4689, 9830, 13040, 24944). Port au Prince, Haiti (133728). Puerto Plata, Dominican Republic (22134). Puerto Rico (50181, 63050, 126445.) Guadaloupe (25285). St. Lucía (142833). Fort Randolph (148675), Porto Bello (80969, 81595, 81601), and Fox Bay (80968, 81596-7, 81602-4), Panama. Río Atrato, Colombia (1681). Brazil (6944). Total examined, 67 specimens 32-181 mm., the largest from Cuba (13040).

This species does not seem to range north of southern Florida. No specimens from north of Key West were examined. Records in the literature ascribing *grandicornis* to Cape Cod probably originated in a misidentification, as one lot in the National Museum (58876) from Katama Bay, Marthas Vineyard, containing four specimens 37-53 mm. and labeled *grandicornis,* proved to be the young of *plumieri.*

While no definite depth records are available, *grandicornis* seems to be an inshore, shallow-water species.

Comparison.—The characteristic small white spots at the pectoral angle, together with the absence of the frontal spine permit the ready identification of this species. The frontal spine is present in small specimens, but it is smaller than in specimens of related species of similar size. The tentacle at the base of the supraocular spine is longer and thicker than in the other species, but individual variants of *brasiliensis* and *plumieri* have this tentacle developed nearly as well. On the whole, taking all its characters into consideration as outlined above, this species is not difficult to distinguish.

SCORPAENA BERGI Evermann and Marsh

Scorpaena bergii Evermann and Marsh, Bull. U. S. Fish Comm., vol. 20, pt. 1, p. 276, fig. 83, 1902 (Mayagüez, Puerto Rico).—Longley and Hildebrand, Carnegie Inst. Washington Publ. 535, p. 161, 1941 (Tortugas).

Scorpaena isthmensis Meek and Hildebrand, Publ. Field Mus. Nat. Hist. Chicago, zool. ser., vol. 15, pt. 3, p. 842, pl. 80, 1928 (Porto Bello, Panama).

D.(XI) XII (8) 9. A.III 5. P.16-18. Sc.42-48. GR.3-4+7-10.

Description.—Snout subequal to eye, varying moderately both ways. Interorbital width about one-half eye diameter or moderately less. Maxillary reaching to under posterior margin of eye or that of pupil. Occipital pit and spines on dorsal aspect of head well developed. Anterior portion of parietal ridge usually somewhat better developed than posterior part; upper and lower posttemporal spines subequal; preorbital with 2 free spinous points, the anterior directed forward, the posterior downward; suborbital ridge moderate, usually ending posteriorly in a slight or moderate point, sometimes the point inappreciable; cleithral spine moderate or well developed. First preopercular and its supplemental spine moderate; second spine longer than third and somewhat nearer to first; fifth spine slightly developed or hardly appreciable at surface. Interopercle with a slight or moderate spinous point at its outer upper corner. Development of tentacles very variable in size and number; tentacle at supraocular spine usually well developed, broad, digitated or fimbriated, sometimes small or notably large nearly reaching spinous dorsal, other tentacles and tabs at spines on head, body, and upper part of eyeball varying from moderate to very profuse. Opercle largely scaleless; scales on cheek deeply embedded, hardly appreciable at the surface. Penultimate dorsal spine usually about four-fifths as long as last spine; longest dorsal spine only a little shorter than postorbital part of head. Second anal spine longer than third. Ventral reaching anus or a little behind. Pectoral about reaching a vertical through base of first anal spine, varying a little both ways; in the larger specimens usually 1 upper ray unbranched, sometimes upper 2 unbranched, next 4-5 rays branched, lower 10-12 rays unbranched.

Measurements of 30 specimens 49-87 mm. and 3 specimens 33-47 mm., all from southern Florida: caudal 26.5-32.0 (28.5-32.0), depth 35.0-40.5 (35.5-41.0), head 42.5-46.5 (46.5-48.0), eye 11.4-14.2 (14.1-15.2). One specimen from Long Island 36 mm.: caudal 29, depth 40.5, head 42, eye 12.4. One specimen from Cozumel Island 59 mm.: caudal 26.5, depth 38, head 44, eye 14.3. Two specimens from Puerto Rico 57-76 mm. (types of *bergi*): caudal 27.5-28.0, depth 40.0-41.5, head 46.0-47.5, eye 15.1-16.1. One specimen from Panama (type of *isthmensis*): caudal 32, depth 38, head 42.5, eye 12.2. Five specimens 59-92 mm. and 3 specimens 33-43 mm. from the entire range of the species: ventral 25-30 (26-30), pectoral 29.5-34.0 (28.0-33.5), maxillary 20.5-24.5 (21.0-23.5), snout 11.1-13.0 (13.8-15.2), interorbital 5.3-6.3 (6.4-7.6); snout 0.9-1.3 (0.9-1.0) and interorbital 2.1-2.6 (2.4-2.8) times in eye.

Rather irregularly pigmented with brown shades against a somewhat lighter background; the pigment somewhat more concentrated on posterior part of body, at end of dorsal and anal fins, forming an irregular, not sharply defined, broad cross band; another band, more irregular and not as marked, at caudal base; the area between the two bands rather abruptly lighter (distribution of pigment in region of caudal peduncle resembling that of *plumieri*); caudal with 3 somewhat irregular, broad, cross bands at base, at distal margin and in between; spinous part of dorsal rather irregularly pigmented, the pigment especially concentrated on an area between third, fourth, or fifth to seventh or eighth dorsal spines, forming a spot only slightly distinguishable from surrounding pigment in dark specimens, well marked in light-colored or faded specimens; anal, pectoral, and soft dorsal with irregular alternate light and dark areas; ventral light-colored or moderately pigmented on its distal part.

Development.—The third and fourth pectoral rays are forked for a short distance in the smallest specimen examined, 33 mm. In a 36-mm. specimen all rays are still unbranched. In the next size examined, 43 mm., the second to the fifth rays are rather well branched. The nuchal pit is rather shallow in the 33-mm. specimen. It is developed nearly as in the adult at about 50 mm.

Specimens examined.—Porto Bello, Panama (81617, holotype of *isthmensis,* 92 mm.). Mayagüez, Puerto Rico (49533, holotype of *bergi,* 76 mm.). Culebra Island, Puerto Rico (126190, paratype of *bergi*). Cozumel Island, Mexico (37103). Tortugas (one specimen 55 mm. in 117138; 117137, 29 specimens 43-87 mm., all other lots consisting of one specimen each), Key West (119119), Palm Beach (153128), and Miami (C.N.H.M. 46214), Fla. Fire Island Inlet, Long Island, N. Y. (108656, 36 mm.). Total examined, 38 specimens 33-92 mm. This appears to be a shallow-water species, although adequate habitat data are unavailable.

Population.—As may be gathered from the measurements given above, the Puerto Rico population seems to average a comparatively deep body, long head, and large eye. The Panama population might be found to average a high pectoral count, and the relative length of the second and third anal spines might differ with the population as discussed below.

Extreme variants and other possible population differences.—The two holotypes examined are both extreme variants in relation to the composite sample examined.

The holotype of *bergi* has 11 dorsal spines, while all other 37 specimens have 12 spines.

The type of *isthmensis* is an extreme variant in four characters: (1) It has 18 pectoral rays, while the other 37 specimens have 17 or 16 rays. (2) It lacks a spine on the suborbital ridge. In the other specimens, 32 have a spine on both sides in various stages of development from well marked to slight, 3 lack the spine on one side and 1 lacks it on both sides. (3) The end of the third anal spine is broken off in the type specimen; but judged by the larger part left and its persistent sheath of skin, it was probably not much shorter than the second spine, the relative length of the two spines in the living fish probably was as in the variant from Long Island discussed below. (4) It is very dark-colored and the spot on the spinous dorsal not sharply marked.

The long caudal of the type of *isthmensis* by which, in the original description, it is said to differ from *bergi*, does not hold, as five of the other specimens examined have the caudal about as long.

The small specimen, 36 mm., taken on Long Island, shows three differences as compared with the other specimens: (1) The head measurement, 42 percent, is unusually low for its size, not only as compared with the other specimens of *bergi* of similar size, but also with other western Atlantic species of *Scorpaena* examined. (2) In the other specimens of *bergi* the tip of the second anal spine reaches beyond that of the third when both are depressed, while in this specimen the tips of the two spines are about coterminal when depressed. (3) The distribution of the pigment on the caudal is somewhat different. Its posterior half is rather diffusely and almost uniformly pigmented, except for a narrow, almost clear marginal area; the base is deeply pigmented transversely; the two pigmented areas are separated by a broad, transverse, nearly clear area.

The relative shortness of the head of the Long Island specimen might be explained by presuming that the specimen is precocious in this respect, having assumed the adult head length at a small size. The difference in the relative length of the second and third anal spines might be a population difference. At any rate, in the absence of conclusive evidence, a shade of doubt exists in the identification of this specimen with *bergi.*

Comparison.—This species averages the lowest pectoral count of all its congeners. The gill rakers average lower than in most species. It is a small species and its pectoral rays are branched at a comparatively small size. In this respect it is near to *albifimbria.* In most characters *bergi* is nearest *grandicornis* and *albifimbria.* It differs from both in usually having a fairly well-marked spot on the spinous dorsal. It further differs from *grandicornis* in having the frontal spine well developed, and in averaging a slenderer body and fewer pectoral rays and gill rakers, the extent of intergradation in the latter three characters being considerable. From *albifimbria* it differs in having a slenderer body and fewer pectoral rays and gill rakers. As only the type of *albifimbria* and one uncertain specimen are available the extent of divergence between it and *bergi* could not be determined adequately.

Synonymy.—As discussed above, the type specimen of *isthmensis* differs somewhat from the norm of the composite sample of *bergi* examined. However, it about agrees in the color pattern and in the important structural characters with the types and other specimens of *bergi.* There are no well-marked specific differences such as distinguish other scorpaenid species, or species of fishes in general. Evidently, the differences noted are either individual differences or they might prove to be minor population differences on examination of adequate samples. The name *isthmensis* is therefore placed in the synonymy of *bergi.*

SCORPAENA ALBIFIMBRIA Evermann and Marsh

Scorpaena albifimbria EVERMANN and MARSH, Bull. U. S. Fish Comm., vol. 20, pt. 1, p. 275, fig. 82, 1902 (off Culebra Island, Puerto Rico).

D.XII 9. A.III 5. P.19. Sc.42. GR.5+10.

Description.—Eye larger than snout. Interorbital about two and a half times in eye diameter. Maxillary ending under posterior margin of pupil. Occipital pit moderate. Anterior part of parietal ridge somewhat longer than posterior part; upper and lower posttemporal spines subequal, well developed; preorbital with 2 well-developed free spinous points; suborbital with 3 spinous points; cleithrum with a blunt projection. First preopercular spine well developed, supplemental spine moderate; second spine about as long as and more slender than third, somewhat nearer to first; lower 3 spines rather broad and blunt, gradually decreasing in size downward. Upper outer corner of interopercle ending in a blunt point. A long tentacle at base of preocular and supraocular spines, rather broad and somewhat fimbriated proximally, slender distally; other tentacles and tabs in very moderate numbers; head and upper part of eyeball with many papillae. Scalation at preopercular margin rather well expanded backward, but greater part of opercle scaleless; scales on cheek and behind eye well embedded. (Spinous dorsal damaged and relative length of spines indeterminable; see below relative length of spines in uncertain variant examined.) Second anal spine longer than third. Ventral falling a little short of base of first anal spine. Pectoral reaching a vertical through base of second anal spine; its first ray unbranched, next 5 rays branched, lower 13 rays unbranched.

Measurements of a specimen 43 mm.: caudal 31.5, ventral 29.5, pectoral 30.5, depth 43.5, head 49, maxillary 27, snout 13.3, eye 17.2, interorbital 7.2; snout 1.3 and interorbital 2.4 times in eye.

Pale yellowish, washed with whitish in places; pectoral with small white spots, and moderately dusky distally; other fins plain; no distinctive color marks. Published figure of specimen examined, made when recently preserved, shows a dark area behind head over lateral line, and soft dorsal and anal with spots and a band respectively.

Specimen examined.—Off Culebra Island, Puerto Rico, 15 fathoms, 43 mm. (49532, the holotype).

An uncertain variant.—A specimen having the following data possibly belongs to this species: Off Palm Beach, Fla., 40 fathoms, Thompson and McGinty, February 1950 (153127), length 44 mm., caudal 32, ventral 31.5, pectoral 33, depth 46.5, head 50.5, maxillary 25, snout 13.3, eye 17.2, interorbital 6.3; snout 1.3 and interorbital 2.7 in eye.

D.XII 9. A.III 5. P.17. Sc.46. GR.5+11.

The counts and measurements of this specimen agree rather well with those of the type given above, except that it has 17 instead of 19 pectoral rays. It further agrees in having the second to the sixth pectoral rays branched, in its almost uniformly pale color, in general appearance, and in the other characters given above, with the following exceptions, besides the difference in the number of pectoral rays. The suborbital ridge ends in 1 moderate spinous point at the end, instead of having 3 spinous points. The second preopercular spine is smaller than the third, instead of being subequal to it. The tips of the second and third anal spines end at the same point when depressed, while in the type the tip of the second spine extends beyond that of the third. The cleithral spine is better developed than in the type. The tentacle at the supraocular spine is broader, and the one at the preocular spine much shorter, than in the type specimen.

Judged by intraspecific variability in other species of *Scorpaena* the differences outlined might well fall within the range of variation of the same species; but this conclusion needs to be confirmed by the study of an adequate sample. Meanwhile, the type and the other specimen concerned are described separately to call attention to the differences, and the counts of the type only are entered in the tables.

The twelfth dorsal spine is damaged in the type. In the variant the penultimate spine is approximately one-half as long as the last.

Comparison.—This is evidently a small species. The pectoral rays are branched at a size at which they are still unbranched in the other species of *Scorpaena,* except *bergi.* It is compared with *bergi* under its account. In general appearance, especially in body shape, the type specimen of *albifimbria* examined somewhat resembles small specimens of *plumieri;* but in specimens of *plumieri* of comparable size all pectoral rays are unbranched, the interorbital is much wider, the cleithral spine much better developed and they are deeply pigmented with a specific color pattern.

SCORPAENA DISPAR Longley and Hildebrand

Scorpaena dispar LONGLEY and HILDEBRAND, Carnegie Inst. Washington Publ. 517, p. 24, fig. 12, 1940 (Tortugas, Fla.).

Scorpaena similis GUNTER, Copeia, 1948, pt. 3, p. 161 (off the Mississippi Delta, La.).

D.(XI) XII 8-9. A.III 5. P.17-19. Sc.42-48. GR.5+10-12.

Description.—Eye moderate, usually a little smaller than snout, sometimes subequal to it. Interorbital about one-half the eye. Maxillary ending under space between posterior margin of pupil and that of eye. Occipital pit and spines on head well developed. Lower posttemporal spine larger than upper; preorbital with 3 free spines, the middle one close to and usually smaller than anterior spine; suborbital ridge usually with 3 spines, sometimes middle spine absent; cleithrum with a moderate spinous projection. Preopercular spines moderate, supplemental spine large in comparison, first spine extending less than half the distance across opercle, next three spines subequal or slightly graduated, fifth spine slight or obsolescent. Upper posterior corner of interopercle forming a blunt projection or ending in a spinous point. Tentacle at supraocular spine very variable, broad, and long to short; other tentacles, tabs, or filaments on body, head, and eyeball variable, usually rather sparse. Scalation on opercle very variable, area below lower ridge scaled or naked in greater part, or covered with partly nonimbricate scales in profusion or in sparse numbers; scales on cheek and opercle moderately or well embedded. Penultimate dorsal spine about two-thirds as long as last spine; longest dorsal spine subequal to postorbital part of head or slightly shorter. Ventral reaching anal origin or a little short. Pectoral about reaching a vertical through base of first anal spine, varying slightly both ways; its first ray unbranched, next 6-8 rays branched, lower 9-11 unbranched.

Measurements of 4 specimens 167-192 mm. and 2 specimens 106-111 mm.: caudal 29.5-31.5 (30.0-30.5), ventral 25.0-26.5 (26-27), pectoral 32.0-35.5 (29.5-33.5), depth 35.0-38.5 (35.0-36.5), head 45-48 (45.0-45.5), maxillary 22-25 (21.0-21.5), snout 13.5-15.6 (12.5-13.9), eye 11.3-12.7 (12.2-12.7), interorbital 5.8-6.1 (5.1-6.0); eye 1.1-1.3 (1.0-1.1) times in snout, interorbital 1.9-2.1 (2.0-2.5) times in eye.

Plain-colored without well-defined color marks; caudal rather faintly marked in two transverse areas, near the middle and near its distal margin, with diffuse small spots; similar spots on pectoral and, to a lesser extent, on soft dorsal and anal still fainter. One specimen has a faint blotch, directly over lateral line at some distance behind head, and a faint elongate blotch directly below lateral line a little farther behind. The above color description is drawn from specimens on the coast of the United States; those from off Cabo Catoche differ somewhat in color as follows. The caudal has elongate, rounded, rather clear-cut brown spots which are generally situated on the interradial membrane, and a few such spots are often present also on the pectoral, dorsal, and anal; while the much fainter spots on the United States specimens are generally situated partly on the rays.

Development.—Two specimens 50-60 mm. already have some of the pectoral rays branched, but the extent of branching is less and the number of branched rays is fewer than in the larger specimens. The same two specimens have the occipital pit and the middle preorbital spine nearly as in the large specimens.

Specimens examined.—Cape Florida (124304) and Tortugas (108-867, holotype of *dispar*), Fla.; off Mississippi Delta (124332, holotype of *similis*, and 155332, both collected by the *Pelican*); off Cabo

Catoche, Yucatan Peninsula, Mexico (101537, 119768, 134220). Total examined, 4 specimens 60-195 mm. from the coast of the United States and 12 specimens 50-207 mm. from off Cabo Catoche. Available depth records range 21-95 fathoms.

Comparison.—This species and *plumieri* differ from their other congeners, except *Microlepis,* in having 3 free spinous points on the distal margin of the preorbital and their distinguishing characters are, therefore, contrasted in the key. However, in general appearance these two species are rather unlike, and it is doubtful whether they are closely related.

Populations.—As noted above, the specimens examined from off Cabo Catoche differ moderately in color as compared with those from the coast of the United States. In the few specimens examined, those from Cabo Catoche average fewer pectoral rays. Counting the rays on both sides, the frequency distribution is as follows, the figures inside the parentheses giving the number of pectorals on which a stated count is based: United States 17 (2), 19 (6); Cabo Catoche 17 (5), 18 (17), 19 (1). Also, both variants having 8 dorsal rays, as shown in table 1, are from Cabo Catoche. The differences indicated point to the need of further research in regard to the precise differences between the two populations, but the specimens examined are altogether too few to form the basis for definite conclusions.

SCORPAENA PLUMIERI Cuvier and Valenciennes, sensu lato

D.XII (8) 9. A.III (4) 5 (6). P.18-21. Sc.42-49. GR.4-6+8-12.

Description.—Eye about two-thirds as large as snout. Interorbital subequal to eye, varying a little both ways. Maxillary ending approximately under posterior margin of eye. Occipital pit rather well developed or moderate; a pit under anterior margin of eye, above suborbital ridge (the only species having a definite pit in this position). Spines on head rather coarse, broadened below apex; lower posttemporal ridge somewhat better developed than upper; preorbital with 3 free spinous points, middle spine small and placed near anterior spine (occasionally absent on one side); suborbital ridge usually with 3 spinous points, sometimes a fourth small point in front; cleithral spine moderate or well developed in the smaller specimens, becoming blunt with growth; in large specimens cleithrum markedly projecting upward and somewhat backward, the two distal corners of the projecting part forming tapering, sharp or rather blunt angles with a well-developed emargination between them, the lower outer angle representing the cleithral spine of the smaller specimens; upper outer angle of interopercle blunt or moderately sharp. Preopercular spines rather short, first spine not extending halfway across opercle; supplemental spine moderate or well developed, usually placed on upper surface of first spine; second spine slightly longer and sharper than third; fourth spine moderately sharp or blunt; fifth spine blunt or obsolescent. Tentacle at supraocular spine very variable from short to long; other tentacles, tabs, and filaments very variable in number and development. Greater part of opercle scaled, but extent of scalation on part below lower ridge very variable, often the scales nonimbricate in part, hard part of opercle between the two diverging ridges usually scaleless as in its congeners, often some nonimbricate scales present; scales on cheek, opercle, and sometimes also on chest more or less embedded. Penultimate dorsal spine averaging about seven-eighths as long as last; longest dorsal spine considerably shorter than postorbital part of head. Second anal spine more or less longer than third. Ventral reaching anus, but more often a little behind. Pectoral usually falling a little short of a vertical through base of first anal spine, sometimes reaching there; its uppermost ray unbranched, next 5-10 rays branched, lower 9-14 rays unbranched.

Body with two variably dark areas, one directly behind head, the other under soft dorsal, separated by a variable lighter area; the three areas very variable in extent and intensity of pigmentation, without clear-cut boundaries, not uniformly pigmented, mottled with lighter and darker shades; caudal peduncle light, usually almost uniformly and strikingly so; a slightly curved cross band at caudal base; an oblique band forking from middle of latter band, downward and forward to underside of peduncle, leaving a light triangular area, bounded by the two bands, at lower part of peduncle; inner surface of pectoral with a black area at its base, spotted with white, usually this pattern extending for some distance on side; caudal with two broad, dark, mottled, transverse areas, one at middle, one at margin; pectoral with three similar transverse areas, not as well marked; soft dorsal and anal mottled before and behind, separated by a nearly clear area in middle; greater distal part of ventral mottled; spinous dorsal often with a black or brown spot, or a row of spots, saliently outstanding from rest of pigmentation; often prettily marbled with white all over the light and dark areas on head, body, and fins.

Growth changes in the color pattern and structural characters are described below under the account of the subspecies *plumieri*, of which a fair sample in a graded size range is available for examination. Small specimens of the subspecies *mystes* are not available for study.

Comparison.—This species has a distinctive color feature which is of much value in distinguishing it from other species of its genus, namely, the inner region at the pectoral base is black with small white spots, sometimes partly confluent, the distinctively colored area extending partly on the side and partly on the surface of the fin. The caudal peduncle stands out from the rest of the body as lighter-colored, uniformly so or more or less shaded. The distinctive combination of structural characters is as follows: 18-21 pectoral rays; 42-49 cycloid scales; total number of gill rakers and tubercles on both limbs 12-17; occipital pit moderate to well developed; 3 preorbital spines. It has a comparatively wider interorbital and smaller eye than its other western Atlantic congeners. The fairly marked pit between the suborbital ridge and eye, under its anterior margin, is unique for this species.

The larger specimens of this species are readily distinguished by the combination of their distinctive color and the structural characters given above and in the key. Small specimens have their distinctive color and the same structural characters, except that the occipital and suborbital pit and the middle preorbital spine are as yet undeveloped (see below under the subspecies *plumieri*).

This species is doubtfully divisible into two supspecies, *plumieri* in the Atlantic and *mystes* in the Pacific. As discussed below under *mystes,* the difference between the two possible subspecies is slight, and it is a question whether they should be so treated. Evidently *plumieri,* sensu lato, is one of those comparatively few species of fish, the Atlantic and Pacific populations of which have diverged but little since their long isolation.

SCORPAENA PLUMIERI PLUMIERI Bloch

Scorpaena plumieri Bloch, Nya Handl. Stockholm, pt. 10, p. 234, 1789 (Martinique).

Scorpaena bufo Cuvier and Valenciennes, Histoire naturelle des poissons, vol. 4, p. 306, 1829 (Martinique).

Scorpaena scrofina Cuvier and Valenciennes, ibid., vol. 9, p. 465, 1833 (Brazil).

Scorpaena rascacio Poey, Memorias sobre la historia natural de la Isla de Cuba, vol. 2, p. 169, 1860 (Cuba).

Scorpaena albofasciata Metzlaar, Rapp. Vissch. Kol. Curaçao, edited by J. Boeke, vol. 2, pt. 1, p. 145, fig. 43, 1919 (Curaçao).

Scorpaena nuttingi Evermann and Seale, Stud. Nat. Hist. Univ. Iowa, vol. 10, p. 39, pl., 1924 (Carlisle Bay, Barbados).

Scorpaena colonensis Meek and Hildebrand, Publ. Field Mus. Nat. Hist. Chicago, vol. 15, p. 844, pl. 81, fig. 1, 1928 (Colón, Panama).

Scorpaena ginsburgi Gunter, Copeia, 1942, p. 105 (Texas).

D.XII (8) 9. A.III 5 (6). P.18-21. Sc.42-49. GR.4-6+8-12.

Description.—Measurements of 14 specimens 206-306 mm. and 3 specimens 33-43 mm.: ventral 27.5-30.5 (29-31), pectoral 33.0-36.5

(29.5-31.0), maxillary 20.5-24.0 (23.0-24.5), snout 12.6-15.0 (12.3-13.2), eye 7.6-9.4 (11.9-13.2), antedorsal distance 35.5-38.5 (41.5-44.0), depth of peduncle 10.6-12.2 (11.2-12.0); eye 1.4-1.9 (1.0-1.1) in snout, interorbital 0.8-1.2 (1.0-1.2) in eye. Measurements of caudal, depth, head, and interorbital given in table 12.

Within the limits of the specific color pattern as described above, many specimens of this subspecies show the following minor characteristics: Variegated dark and light or white markings on body and fins very notable; black area at pectoral axil very deeply pigmented, the white spots in the area very sharply contrasted, comparatively rather large, and usually extend also on side of body; light area on caudal peduncle sharply contrasted with the dark pigment before and behind; small spots on lower part of sides few and diffuse or absent. However, color markings vary much with the individual and one or all of the preceding color characteristics are not present in many of the specimens examined.

Development.—Small specimens, under 50 mm., have a characteristic and distinctive color pattern as follows: Head and body almost uniformly very dark, in sharp contrast the caudal peduncle abruptly very light, without melanophores, except the characteristic forking band described above under the species; posterior part of dorsal and anal likewise clear; a vertical nearly straight line marking anterior boundary of clear part of peduncle and dorsal and anal fins; rest of dorsal and anal, and ventral and pectoral almost uniformly very dark except that pectoral has a narrow whitish margin; color of caudal nearly as in grown specimens. The change from the juvenile to the adult color pattern occurs early and rather rapidly. The adult color pattern is not radically different; it is merely a modification of the juvenile pattern. The characteristic white spots against a black background in the pectoral axil begin to appear at about 40 mm.

At 30 mm. the occipital pit is virtually absent, the area occupied by the pit in the adult being only slightly depressed, almost flat for its greater part. It reaches its full development at about 90 mm. In the largest specimens it becomes again rather shallow, and also comparatively broader.

The suborbital pit begins to appear between 60 and 70 mm., and a trace of the middle preorbital spinous point somewhat later, between 65 and 75 mm. The pectoral rays begin to branch at about the time the suborbital pit begins to develop.

Specimens examined.—Katama Bay, Marthas Vineyard, Mass. (49677, 58876, 58901-2; altogether 7 specimens 30-53 mm.). Beaufort, N. C. (53407, 111509, 126501; altogether 3 specimens 64-87 mm.). Biscayne Bay (61704) and Tortugas (6777, 41839, 117136, 117140), Fla. Corpus Christi (148135), Harbor Island (148134, 148136), Aransas Pass (119016, holotype *ginsburgi*), Mustang Island (119015, 119017-8), and Freeport (157559), Tex. Abaco, Bahamas (38387-8). Cuba (4688; 10126; 12543; 35096; 153578, cotype *rascacio*). Jamaica (30005, 30087, 35120, 38565). Haiti (122640, 133727). Puerto Rico (50149). Dominica (29854). St. Lucía (41333). Old Providence Island (38631). Fort Randolph (128702), Colón (81606, holotype *colonensis*), Fox Bay (80978-80, 81591-2), and Porto Bello (80973-4, 81593-4), Panama. Cabo San Román (123197) and Gulf of Venezuela (123196), Venezuela. São Paulo market (100875) and Santos market (100876), Brazil. Total examined 69 specimens 30-323 mm., the largest from Cuba.

This subspecies is the most widespread of all scorpaenids here treated, ranging from Massachusetts to Brazil, and it is fairly common. The northern specimens examined are all small. It lives inshore and also ranges offshore.

TABLE 11.—*Frequency distribution of the number of pectoral rays, scales, and gill rakers in some populations of the subspecies* plumieri.

	Pectoral rays				Scales								Gill rakers, total					
	18	19	20	21	42	43	44	45	46	47	48	49	12	13	14	15	16	17
Massachusetts	..	..	7	..	..	2	1	1	1	2	..	..	..	..	1	3	3	..
Texas	..	12	2	..	..	..	2	1	3	2	3	2	..	1	3	8	2	..
Cuba	..	1	5	..	1	2	..	2	1	..	..	..	..	..	..	1	4	1
Jamaica	..	5	..	..	..	..	..	2	1	2	..	..	..	..	3	2	..	..
Panama	2	9	1	1	1	..	3	6	2	1	..	..	1	1	1	5	4	..

Comparison.—This subspecies is compared with *mystes* under the account of the latter.

Populations.—Table 11 shows population differences in the frequency distribution of the number of pectoral rays, scales, and gill rakers. The gill-raker count gives the total number on the outer arch, including the gill rakers and tubercles on both limbs. While the samples are too small to serve as a basis for definitive conclusions, they at least give an indication of some of these differences.

The predominant number of pectoral rays is either 19 or 20, depending on the population. In the subspecies *mystes,* in 12 specimens representing a wide geographic range, the number is constantly 20. However, in *plumieri* the differences in the number of pectoral rays evidently cannot be correlated with geographic distribution or with other structural differences. Besides, the count within the range of a given population is not absolutely constant. Consequently, this count cannot serve as a basis for subspecific distinction.

The scale count is low on the average in the Cuba and Panama populations and highest in that of Texas. The gill-raker count is low in the Jamaica and Panama populations and high in that of Cuba.

The caudal in small Texas specimens is appreciably longer as compared with similar specimens from Katama Bay. In 5 Texas specimens 30-52 mm. the caudal length ranges 32.4-34.1; while in 7 Katama Bay specimens 30-53 mm. the range is 28.3-30.9. Larger specimens from Katama Bay are not available for comparison. Texas specimens both large and small, when compared with combined samples of similar specimens from the West Indies and Central America do not show any striking differences in the caudal length.

On the whole, judged by the small samples examined, these minor population differences are not sufficiently divergent to serve as a basis for subspecies distinction.

Synonymy.—The names *bufo* and *rascacio* generally have been synonymized by authors with *plumieri*. One of Poey's cotypes of *rascacio* has been examined and its data included in this account. The original description of *bufo* is recognizable and it was evidently based on specimens of this species. The reasons for placing the other five names in the synonymy are as follows.

In the brief description of *S. scrofina*, it is said to have large white drops ("gouttes") on the pectoral axil, which is a characteristic color mark of *plumieri* and of no other known species. There is nothing in the description of *scrofina* to indicate that the specimen described is different from *plumieri*. It seems safe to conclude that it is an individual variant of this common species.

Metzlaar does not compare his *S. albofasciata* with any other species, nor does he state the reason for establishing a new species. Presumably, he based it on the striking color pattern of his specimens, which is well indicated in his published figure. This color pattern is characteristic of the young of *plumieri* as stated above. Three small specimens, 30 mm., of *plumieri* examined, about the same size as Metzlaar's specimens, are nearly exact replicas of his figure. Although I did not examine the type of *albofasciata,* there is hardly any question that it represents young specimens of *plumieri.*

The type of *colonensis,* 43 mm., which was reexamined, likewise represents a young *plumieri.* According to the character used in their key, *colonensis* was based by the original authors on the near absence of an occipital pit, which is a character of the young. In the type of *colonensis* the state of development of the occipital pit is like that in specimens of *plumieri* of similar size, and its other specific characters agree with this species.

The single type specimen of *nuttingi* is said to differ from *plumieri* in having 5 branched pectoral rays (8 such rays shown on the figure) instead of 1. This is an error, *plumieri* normally having 5-10 such rays, except in the young. The other differences mentioned in the original description of *nuttingi* are largely governed by individual variability. The published figure of *nuttingi* is well executed and it is so typical of *plumieri* in color and general appearance that there seems no doubt that it represents a specimen of that species.

Gunter gives a number of characters which are said to distinguish *ginsburgi* from *plumieri*. However, examination of a larger series of specimens than that available to Gunter shows that those characters are subject to a great deal of individual variation. Any slight average differences that might exist evidently are no more than the slight differences that are usually found between the local populations of the same species. Some of the minor population differences are discussed above. Most any species of fish could be split up into a number of taxonomic units by using such minor population differences. To recognize such minor differences by the formal bestowal of scientific names would make nomenclature too burdensome, and in the present state of ichthyology would serve no useful purpose.

SCORPAENA PLUMIERI MYSTES Jordan and Starks

Scorpaena mystes Jordan and Starks, Proc. California Acad. Sci. (ser. 2) vol. 5, p. 491, pl. 52, 1895 (Mazatlán, Mexico).

Scorpaena tierrae Hildebrand, U. S. Nat. Mus. Bull. 189, p. 441, fig. 84, 1946 (Peru; Chile).

D.XII 9. A.III (4) 5. P.20. Sc.44-47. GR.4-5+9-11.

Description.—Measurements of 5 specimens 199-279 mm.: ventral 27.5-29.5, pectoral 34.0-35.5, maxillary 21.0-24.5, snout 11.5-14.1, eye 8.3-9.7, antedorsal 35-39.5, depth of peduncle 10.8-11.7; eye 1.4-1.6 in snout and interorbital 1.0-1.2 in eye.

The majority of specimens differ in color characteristics from the subspecies *plumieri*, described above, as follows: Variegated dark and white markings on body and fins not as well marked; black area at pectoral axil not as strongly pigmented, and the white spots generally smaller, fewer, not as sharply marked, and usually confined to underside of pectoral fin; light area on the caudal peduncle generally somewhat suffused with a dusky tint, and not as markedly outstanding; small dark spots on lower part of side often well marked. However, there is much individual variation in the relative development of pig-

TABLE 12.—*Range of depth, head, interorbital, and caudal measurements of* Scorpaena plumieri plumieri *and* S. p. mystes, *segregated into size groups, expressed as a percentage of the standard length.*

Subspecies	Length of specimens	Number of specimens	Depth		Head		Interorbital		Caudal	
			Range	Average	Range	Average	Range	Average	Range	Average
plumieri	30-53	15	40.1-47.7	44.1	45.1-50.0	47.4	11.1-13.6	12.1	28.3-34.1	31.2
plumieri	58-110	14	37.5-43.7	40.9	44.4-47.6	45.9	9.1-11.0	9.9	29.0-33.9	31.4
mystes	80-108	2	33.7-35.0	34.4	46.0-46.7	46.4	7.4- 7.5	7.5	29.1-30.8	30.0
plumieri	141-189	12	34.7-41.6	38.6	38.6-46.6	44.2	8.1- 9.9	9.2	27.4-32.2	30.0
mystes	130-192	3	33.9-36.6	35.6	42.5-45.8	43.9	6.9- 8.7	8.1	28.0-30.2	29.1
plumieri	205-280	23	33.3-40.1	35.9	39.2-46.0	43.7	7.6- 9.4	8.5	27.0-31.5	29.3
mystes	199-279	5	29.8-35.2	33.4	42.5-46.7	45.1	7.7- 8.9	8.3	25.0-29.9	28.0
plumieri	287-323	4	31.3-38.9	35.2	43.4-46.6	44.6	8.4- 8.6	8.5	27.3-30.6	28.9
mystes	356	1	....	29.8	....	47.0	....	9.8	....	25.7
mystes	437	1	....	33.6	....	50.2	....	9.2	....	23.6

ments in both subspecies, and color differences do not distinguish them satisfactorily.

Specimens examined.—Bay of Guaymas (43257), Mazatlán (47450, cotype of *mystes*), and Acapulco (65657), Mexico. Taboguilla Island (128730), Taboga Island (80970, 12871), Naos Island (80971), Panama City tide pools (81599), Panama. Lobos de Tierra, Peru (128128, holotype, and 128129, paratype, of *tierrae*). Juan Fernández Island, Chile (88775, paratype of *tierrae,* 437 mm.). Total examined, 12 specimens 80-437 mm.

Comparison.—This Pacific population does not differ much from the corresponding Atlantic population. It differs somewhat on the average in some proportional measurements, as may be gathered by comparing the data given in table 12 and under the accounts of the subspecies, the greatest apparent degree of divergence referring to the body depth. As the depth changes with growth, an adequate appraisal of the precise degree of divergence of this measurement cannot be made with the available specimens. When the scant data included in table 12, in the size groups 130-192 and 199-280 mm., are arranged in the form of a frequency distribution, the apparent degree of divergence shown is less than that of subspecies magnitude.

A direct comparison of specimens shows that, in general, the occipital pit in the Pacific population is shallower. However, in both populations the degree of development of the pit varies with the individual, and changes markedly with growth as described above under the subspecies *plumieri.* It is very difficult to determine the precise degree of divergence of this character as it can hardly be expressed in terms of exact figures. But the difference is evidently not pronounced and individual specimens cannot be identified by its use as a criterion without a knowledge of the locality of capture. The degree of divergence of this character also appears to be less than that of subspecies magnitude.

The two populations also show, in bulk, some differences in color characteristics as described under their accounts; but individually the specimens are indistinguishable by color. This is another character that can hardly be expressed numerically.

On the whole, judged by the samples examined, the degree of divergence between the two populations seems to be of the order of race, rather than subspecies, or the border line between these two categories. But in the absence of conclusive data and considering their long isolation in point of time, it seems best to treat them, at least tentatively, as distinct subspecies, since they have been treated heretofore as distinct taxonomic entities and both have been formally named.

The relative depth of the occipital pit and the interorbital width constitute the two chief characters that have heretofore been used to distinguish the Atlantic and Pacific populations as distinct species. The very limited value of the occipital pit as a taxonomic character in separating these two populations is discussed above. Measurements of the interorbital width are given in table 12. It differs greatly with the size of the fish. When specimens of like size are compared there is a moderate difference in the smaller specimens, but hardly any difference in the size group 199-280 mm.

Synonymy.—The holotype of *tierrae* has the head unnaturally thrown out of shape. Evidently, the fish had the opercles spread outward when rigor mortis set in. This gives the head a broad, flat appearance; but when the opercles are pressed to their approximately normal position, the specimen does not differ materially from others of *plumieri,* sensu lato. Besides the head shape, other differences mentioned in the original description vary with the individual and the state of growth.

A statement used in the original description of *tierrae,* and also in the accompanying key, needs to be emended from the viewpoint of homology and also because it has a bearing on one of the main characters here used to separate the genera and species. The statement is made that *tierrae* has 6 preopercular spines. However, 5 preopercular spines is the typical basic number for all the species here treated, as discussed above, with the first spine having a supplementary spine or spur at its base in most species. In *plumieri,* sensu lato, the supplementary spine usually arises from the upper outer surface of the first preopercular spine, and in individual specimens, especially large ones, it sometimes becomes rather prominent. It might then mistakenly be included in the count of the preopercular spines, which would result in a total count of 6. However, though prominent, it is still the supplementary spine homologically and should not be taken for the first preopercular spine.

SCORPAENA MICROLEPIS Gunter

Scorpaena microlepis GUNTER, Copeia, 1948, No. 3, p. 162, plate 2 (off Englewood, Fla.).

D.XII 9. A.III 5. P.16-18. Sc.76. GR.5+11.

Description.—Eye subequal to snout. Interorbital approximately 2 times in eye. Maxillary ending on a vertical a little in front of posterior margin of eye. Occipital pit rather small and shallow. Anterior part of parietal ridge somewhat higher than posterior part;

frontal spine in a line with postocular placed laterad of parietal ridge; upper posttemporal slightly indicated (on right side of single specimen examined) or absent (on left); lower posttemporal ridge and spinous point moderate; sphenotic doubled; pterotic ridge and spinous point well developed; postorbital in form of very slight tuberosities; preorbital with 3 free spinous points; suborbital ridge with 2 very slight spinous points, 1 under eye, 1 at its posterior end (the anterior point missing on left side, the posterior absent on right side); cleithral spine well developed (on left) or very slight (on right). First preopercular spine reaching about halfway across opercle; supplemental spine slight; lower 4 spines graduated, the second longer than third, fifth slightly developed. Tentacles at supraocular spine moderate, other tentacles sparse (skin on head broken in places). Scales notably small, 76; fleshy pectoral base largely scaled, an area on its posterior lower part naked; scales on chest and pectoral base not embedded; opercle partly scaled over upper ridge (opercle below lower ridge having scalation seemingly incompletely preserved and skin partly destroyed, its greater part probably scaleless); scales in patch on cheek below suborbital ridge embedded and larger than any other. Penultimate dorsal spine about two-thirds as long as last; longest dorsal spine subequal to postorbital part of head. Second anal spine a little longer than third. Ventral nearly reaching anal origin. Pectoral reaching to over base of first anal spine; upper ray unbranched, next 6-8 rays branched (differs on both sides of specimen examined, both counts entered independently in table 2).

Measurement of one specimen 121 mm.: caudal 33.5, ventral 30, pectoral 33, depth 33, head 42, maxillary 19, snout 11.5, eye 10.9, interorbital 5.5; eye 1.1 times in snout, interorbital 2 times in eye.

Head and body a nearly uniform brown; soft dorsal and anal with irregular alternating areas of light and dark shades, similar areas on pectoral slightly perceptible; caudal with a dark transverse area at its base, followed by lighter area, its posterior and greater part diffusely dusky; ventral slightly pigmented.

Specimen examined.—Off Englewood, Fla., Bass Biological Laboratory, January 7, 1936 (U.M.M.Z. 110161, the holotype and only known specimen).

Comparison.—This is a strongly marked species. It is distinguishable from its western Atlantic congeners at a glance by its notably small scales. The occipital pit is small and rather shallow, being somewhat intermediate in this respect between *calcarata* or *inermis* and the other species of *Scorpaena.* The frontal spine is in a line with the postocular, laterad of the parietal ridge as in the above-named two species. In having 3 preorbital spinous points it agrees with *plumieri* and *dispar* and differs from all others.

Genus SETARCHES Johnson

Setarches Johnson, Proc. Zool. Soc. London, 1862, p. 177 (genotype *Setarches guntheri* Johnson, by monotypy).

This genus has a combination of specialized and generalized characters. The unusual structure of the lateral line and the cavernous bones of the skull are evidently specialized features, while the poor development of a number of spines on the head more nearly approaches the generalized fish morphology than other scorpaenid genera. On the whole, considering all the characters, it seems to be a highly specialized genus. The generic characters are included under the account of the single species here treated where its relationship to the other western Atlantic scorpaenids is further discussed.

SETARCHES PARMATUS Goode

Setarches parmatus Goode, Proc. U. S. Nat. Mus., vol. 3, p. 480, 1881 (*Fish Hawk* station 867, off Long Island, N. Y., 39° 57′ N., 70° 56′ W., 120 fathoms).—Goode and Bean, Oceanic ichthyology, p. 264, pl. 70, fig. 249, 1895 (the figure from the type specimen having a mutilated dorsal).

D.XII; 9-10. A.III (4) 5. P.22-24. Sc.88-103. GR.6-7+10-15.

Description.—Skull with large external cavities formed by configuration of skeletal elements, with ridges more or less developed between cavities, externally bridged over by a rather thin membranous skin. Eye smaller than snout. Interorbital comparatively broad, only a little less than eye diameter. Maxillary ending approximately under posterior margin of eye. Palatine teeth present. A small slit on inner side of fourth gill arch. Gill rakers at the angle of the arch rather long and slender, gradually decreasing in length both ways; difference between gill rakers and the tubercle-like outgrowths at ends of arch rather abrupt, the two kinds readily distinguishable; gill rakers on upper limb 3 (in 24) or 4 (17), infrequently 5 (1); gill rakers on lower limb 10 (25) or 11 (15), infrequently 9 (1) or 12 (1); tubercles on upper limb low but their number readily determinable, nearly always 3 or 4, infrequently 2 (in 1 out of 42 specimens); tubercles on lower limb not as well marked, their number difficult to determine with precision (see discussion below), varying 0-5. Occipital region flat, without a pit. Nasal and preocular spines small but sharp; supraocular and postocular absent, except indicated as blunt protuberances in small specimens (the only species here treated lacking these spines); parietal ridge entire, long, low, ending in a single spinous point posteriorly; frontal spine absent; upper posttemporal short or moderate, sharp or rather blunt; lower posttemporal short, blunt, or nearly absent; sphenotic absent, except moderate in young; pterotic ridge and spine moderate; no postorbital spine or tuberosity; preorbital with 3 free spinous points well developed; suborbital ridge smooth, without spinous points; cleithrum with a moderate, blunt projection. The 5 preopercular spines well developed; upper 3 notably long in comparison, subequal, or second spine slightly longer than other two, sometimes first or third slightly longer; supplemental preopercular spine absent; fifth spine directed downward. Tentacles, filaments, and tabs absent. Lateral line a continuous channel, in form of very shallow ditchlike depression covered over by membranous vaulted roof; two rows of very thin, notably elongate, membranous scales forming part of roof, one row arranged in a horizontal series at lower part of roof, the ends of the scales moderately separated or almost touching, another row at upper part of roof containing narrower and flimsier scales somewhat more widely separated and rather obliquely placed (the rooflike structure more or less damaged in nearly all preserved specimens; the modified lateral line present in only this species of those examined). Scales small, cycloid, roundedly oblong, rather moderately imbricated, 88-103 (in four specimens, scales missing in large patches in other specimens); scalation on antedorsal area extending to parietal spines; opercle with a patch of scales above upper ridge, and its thin membranous marginal area more or less scaled, its greater part scaleless; a patch of scales on posterior part of cheek below suborbital ridge; area above suborbital ridge between eye and preopercular margin scaled; rest of head and occiput scaleless. Emargination between spinous and soft parts of dorsal notably developed, virtually forming two separate fins, eleventh spine about one-third as long as twelfth; longest dorsal spine subequal to snout length. Second anal spine shorter than third. Ventral falling considerably short of anus, its outer angle under lower pectoral angle. Pectoral irregularly wedge-shaped, the longest rays near its middle, but lower outline notably more curved than upper; fin reaching to over base of second anal spine or a little shorter, its upper 2 or 3 rays unbranched, next 12-16 rays branched, lower 5-9 rays unbranched. Caudal slightly emarginate or truncate.

Measurements of 3 specimens 115-167 mm.: caudal 24.5-27.5, ventral 19-21, pectoral 33.5-34.5, depth 32.0-35.5, head 40.0-43.5, maxillary 22.0-24.5, snout 12.3-13.6, eye 9.5-10.8, interorbital 8.4-9.2; eye 1.2-1.3 times in snout, interorbital 1.1-1.2 times in eye.

Recently preserved specimens having the head, body, and inner face of opercle suffused somewhat irregularly with a dusky shade; upper part above lateral line often with very small dusky or dark spots of a deeper shade than ground color; fins mostly yellowish, very moderately suffused with dusky; palate black; no distinctive markings; specimens long in preservative almost uniformly plain yellowish.

Development.—Although this is a small species the pectoral rays begin to branch comparatively late, at about 80 mm. Rudiments of supraocular, postocular, and sphenotic spines are evident in five specimens 49-58 mm. as blunt protuberances. Slighter traces of these spines persist up to 70 mm. and generally disappear at 80 mm.

Gill rakers.—The tubercles on the upper limb are low but easily distinguishable and their number varies only moderately with the individual. However, the precise enumeration of the tubercles on the anterior part of the lower limb is attended with some difficulties. They are often only slightly developed, especially in small specimens, and not easily observed. Sometimes they apparently coalesce and are not distinguishable individually. It seems also that supernumerary tubercles that are hardly distinguishable from the regular tubercles sometimes appear with growth. Some evidence points to the possibility of their being absent or few in the young and appearing after some growth has been attained. On top of this, the number of tubercles appears to vary widely with the individual. As a consequence, the number of tubercles on the lower limb constitutes an unstable and unsatisfactory specific character, and of course this also applies when the number of these tubercles is combined with the gill rakers into a single figure. On the other hand, in this species, unlike the condition in other scorpaenids here treated, the gill rakers are distinguishable readily from the tubercles, they vary within narrow limits, and their number given separately constitutes a well-marked, comparatively stable specific character. Therefore, under the above description the frequency distribution of the number of gill rakers only is stated separately; while in tables 3-5 and in the formula at the head of the species account the combined number of gill rakers and tubercles is given for the purpose of comparison with the other species, but these numbers are not as valuable taxonomically as the gill-raker numbers alone.

Specimens examined.—Off the following localities: Long Island, N. Y. (26084, the holotype). Cape Charles, Va. (46074). Cape Lookout, N. C. (57817). Savannah, Ga. (155333). Tortugas (92059, 117146), Egmont Key (157553, 157556), and Cape San Blas (44672, 46081), Fla. Horn Island, Miss. (157554). Isle Derniere, La.

(157555). Padre Island, Tex. (157568). Barbadoes (47644). Total examined, 42 specimens 49-167 mm., the largest from off Cape San Blas. Depth records, available for 11 of 13 constituent samples examined, range 93-280 fathoms.

Comparison.—This species differs from all other western Atlantic scorpaenids in having very small cycloid scales, in the peculiar structure of the lateral line, in having the upper 3 preopercular spines long, slender, and subequal or nearly so, in lacking the supraocular and postocular spines, and in the virtual presence of 2 dorsal fins. It has notably well-developed cavities at the surface of the head skeleton that are bridged over by the thin membranous skin. It is apparently the most specialized species as compared with the others here treated.

LITERATURE CITED

CLEMENS, W. A., and WILBY, G. V.
1949. Fishes of the Pacific coast of Canada. Fisheries Res. Board Canada Bull. No. 68 (revised).

FOWLER, HENRY W.
1938. Descriptions of new fishes obtained by the United States Bureau of Fisheries steamer *Albatross,* chiefly in Philippine seas and adjacent waters. Proc. U. S. Nat. Mus., vol. 85, pp. 31-135.

GINSBURG, ISAAC.
1938. Arithmetical definition of the species, subspecies and race concept, with a proposal for a modified nomenclature. Zoologica, vol. 13, pp. 253-286.
1951. Western Atlantic tonguefishes with descriptions of six new species. Zoologica, vol. 36, pp. 185-201, pls. 1-3.

GREGORY, WILLIAM K.
1933. Fish skulls: a study of the evolution of natural mechanisms. Trans. Amer. Philos. Soc., n. s., vol. 23, pt. 2.

GUNTER, GORDON.
1948. Notes on fishes of the genus *Scorpaena* from the south Atlantic and Gulf coasts of the United States, with descriptions of two new species. Copeia, No. 3, pp. 157-166, pls. 1-2.

JORDAN, DAVID S., and EVERMANN, BARTON W.
1898. The fishes of North and Middle America. U. S. Nat Mus. Bull. 47, pt. 2.

MIRANDA RIBEIRO, ALIPIO DE.
1915. Arch. Mus. Nac. Rio de Janeiro, vol. 17, Scorpaenidae, pp. 1-9.

SCHULTZ, LEONARD P.
1943. Fishes of the Phoenix and Samoan Islands collected in 1939 during the expedition of the U. S. S. *Bushnell.* U. S. Nat. Mus. Bull. 180.

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A MORE COMPREHENSIVE DESCRIPTION OF *BACTERIUM SALMONICIDA*

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ABSTRACT

The purpose of this study was to establish a set of descriptive data which could be used as a reference or a standard in the identification of *Bacterium salmonicida*, the cause of furunculosis in fish. Since a complete description of *B. salmonicida* was not available, bacteriologists were not in a position to identify this microorganism in a manner which would meet the rigorous requirements of present-day bacteriology.

Ten strains of *B. salmonicida* were employed in these studies. A detailed description is presented which includes the morphological, cultural, and physiological characteristics of *B. salmonicida*. In addition, various factors such as oxygen, pH, temperature, and composition of media are discussed in terms of their influence on the formation of the melanin-like pigment which is characteristically produced by this microorganism.

INTRODUCTION

Bacterium salmonicida is the etiological agent of furunculosis in certain species of fish, particularly among the Salmonidae. The first description of this microorganism was given by Emmerich and Weibel in 1894 and since that time, many reports have appeared relating to the characteristics of this bacterium. However, a survey of the literature points to a surprising lack of agreement with respect to the physiological and biochemical characterization of *B. salmonicida*. A complete description of an unequivocal nature is therefore lacking and as a consequence only superficial reference to this microorganism can be found in Bergey's Manual of Determinative Bacteriology (1948). The situation is anomalous in view of the widespread occurrence and considerable economic importance of the disease caused by this bacterium. Accordingly, an investigation was undertaken to establish a set of descriptive data which could be used as a reference or a standard in the identification of this microorganism.

Much of the confusion concerning the description of *B. salmonicida* has had its origin in a failure to recognize the influence of oxygen, pH, and composition of the medium used in cultivation techniques. These factors are particularly applicable to the formation of the characteristic amber-black pigment which is primarily used as the criterion for presumptive bacteriological diagnosis of this type of infection in fish.

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It should be noted that the results of past experimental work are scattered in the literature, making it difficult for one to become familiar with the research which has been completed. Fortunately, this difficulty was overcome since an excellent and comprehensive review has appeared on furunculosis of fish (McCraw, 1952). The reader is therefore referred to this work for references concerning many of the original descriptions with which the present study agrees or disagrees

METHODS

Ten cultures of *B. salmonicida* (S-1, 7, 9, 14, 17, 18, 20, 22, 23, 25) were utilized in these studies. All of the strains had been isolated from diseased fish obtained from widely scattered sections of the United States. The cultures were maintained at 6° C. on trypticase-yeast extract agar slants. Prior to each test, the microorganisms were transferred to fresh slants and incubated at 22° C. for 24 hours. A subculture was then made in nutrient broth (Difco) for the same time and temperature as indicated above. These subcultures then served as the inoculum for all of the tests to be described. Unless otherwise indicated, the incubation temperature was 20–22°C.

DESCRIPTION OF THE BACTERIUM

Morphology.—At the end of 18 hours of incubation on nutrient agar at 22° C., the microscopic picture may be somewhat confusing since some strains of the organism frequently exhibit a tendency to pleomorphism. The organism usually grows predominantly as short plump rods with rounded ends which approach a coccus form or the arrangement may take the form of diplobacilli (1 micron wide and 1.7–2 microns long) or chains of variable length; many coccoid forms (approximately 1 micron in diameter) singly and in pairs, are also evident. Filaments and definite cigar-shaped structures (8 microns long and 1 micron wide) and bipolar rods also may be found; it is not uncommon to find fused filaments as long as 40–50 microns. After 48 hours, there is a predominance of coccoid forms (approximately 1 micron diameter), singly and in pairs; diplobacilli are also present. In nutrient broth, the appearance of the microorganism is not as markedly coccoid as that described for cells grown on agar. In the former, there are many bacillary forms, singly and in pairs and an obvious tendency exists to form short and long chains of rods which are not usually fused into filaments. Some strains may show an abundance of bipolar rods. After 72 hours in broth or on agar extreme pleomorphism may be manifest in some strains. One may find cocci, rods, paired forms, many cigar-shaped structures, filamentous forms which stain lightly and contain heavily stained beaded areas, and irregular lobulated and enlongated rods. The coccoid forms at this time are usually much larger than those found at 48 hours. In other strains, even at the end of 6 days of incubation in nutrient agar and broth, the pleomorphic tendency is at a minimum and coccoid forms are predominant.

The organisms are gram negative; some tendency to bipolarity has been noted. They are non-motile, non-spore-forming and devoid of capsules (Anthony's method and India Ink technique) and non-acid-fast.

Cultural characteristics.—*B. salmonicida* is a facultative anaerobe growing best with unrestricted access to air. In nutrient broth, the optimum growth temperature was 20–22° C. The maximum growth temperature was 34.5° C., and the minimum temperature tested at which growth appeared was 6° C. The optimum reaction for growth in nutrient broth buffered at various values with buffer tablets was at pH 6.4; a secondary peak of growth stimulation appeared at 7.6 to 8.1. The intensity of growth was measured on a Beckman Model B Spectrophotometer (650 millimicrons). In buffered trypticase-yeast extract broth growth occurred between pH 5.3 and 9.0. Growth did not occur at a pH value of 5.3. Sterilization of the medium above pH 9.0 was considered impractical. Maximum growth occurred between pH 6.3 and 6.6 with a secondary growth peak at pH 8.6. In unbuffered trypticase-yeast extract broth the pH range for growth was between 5.4 and 9.0. Growth did not take place at pH 5.4. The pH values for optimal growth varied little and extended from 6.8 to 8.0. A similar plateau was noted in unbuffered nutrient broth. In nutrient broth after 24 hours of incubation, the growth of some strains was homogeneous in appearance with only a slight fine sediment in the base of the tube. In other strains, the growth had collected as a flocculent mass at the bottom of the tubes with a clear supernatant above. In these latter strains, one occasionally could note a light amount of growth adhering to the walls of the test tubes. In other strains in which homogeneous growth occurred, a small clear area could be detected in the top-most portion of the broth.

On nutrient agar plates, the colonies averaged less than 1 millimeter in diamter in 24 hours. They were punctiform, smooth, entire, convex, translucent to opaque, and without a pigment. At the end of 4 days, well isolated colonies averaged 1 to 2 millimeters in diameter. In 5 days a light straw-yellow color developed which could be reliably discerned only by comparison with an uninoculated control agar plate. In 6 days a light brown color appeared in the medium which was greatest in intensity in the area of heaviest growth. On nutrient agar slants in 24 hours, growth was abundant, filiform, glistening, opaque to transparent, butyrous, odorless, and colorless. A faint indication of pigment production could be noted in 3 days, however by the fifth day a definite light yellow-brown color developed in the medium. This coloration could be seen best by comparison against uninoculated slants.

Scant to negative growth resulted on eosin-methylene blue agar. On blood agar (veal-yeast extract agar plus 10 percent sterile defibrinated rabbit blood), beta hemolysis was exhibited in 48 hours. In 24 hours a brown pigment was noted in the area of heaviest inoculum. After 48 hours, the pigment began to change to an intense brown-black color.

Growth in plain and nutrient gelatin was best at the top with growth extending in a filiform to beaded manner to the base. Liquefaction was crateriform in 24 and 48 hours and changed to infundibuliform in 72 hours.

There was 75- to 90-percent liquefaction in 6 days and it usually was complete at the end of 8 days. A light brown ring of pigment appeared at the top of the gelatin in 9 days in all strains except S–7 and S–14. The latter strains failed to form pigment even after 38 days of incubation in this medium. In 13 days this ring became dark brown and extended downward a quarter-inch from the top; in 20 days the color had changed to a deep amber. On gelatin plates, the medium was pitted in 24 hours and liquefaction occurred along the line of streak. Liquefaction was complete in 90 hours in all but one strain (S–20, 5 days). A decided brownish pigment was produced by all strains in 8 days.

In nitrate broth, nitrates were reduced to nitrites in 24 hours; on nitrate agar the reduction was complete in 48 hours. Hydrogen sulfide was not produced. Hydrolysis of starch occurred in 48 hours and was complete in 3 to 5 days. Indole was not produced. The methyl-red test was negative, acetylmethylcarbinol was not produced, and growth did not occur in Koser's citrate broth; the urease test was also negative (7 days). Ammonia, determined by employing Conway units after the method of Fister (1950) and calculated as ammonia nitrogen, was detected after 8 hours in trypticase-yeast extract agar. There was slight acid formation (pH 6.5) in bromcresol-purple and Litmus milk in 24 hours and peptonization was 25-percent complete in all strains but S–1. Complete peptonization occurred in all strains in 7 days. The pH increased steadily and at the end of 14 days had reached a value equivalent to the uninoculated controls (pH 7.1), as checked in an electric pH-meter. A pigment was not visible at the end of this time. In trypticase-yeast extract, semi-solid agar, containing resazurin, growth extended to the bottom along the line of puncture and the dye was completely reduced in 48 hours. A positive test with paraphenylenediamine was obtained in 18 hours (Griffin, Snieszko, and Friddle, 1952a).

Various sugars, alcohols, and glucosides were sterilized by filtration through Selas porcelain filters (porosity No. 3) and incorporated into standard basal medium in 1-percent concentrations. The data in Table 1 are representative for the 10 strains employed. Unless otherwise indicated, the data represent observations made at the end of 24 hours of incubation at 20° C. All media were maintained for over 1 month before being discarded.

GROWTH REQUIREMENTS

Although good growth was obtained in nutrient broth, far better growth was obtained upon the addition of yeast extract (Difco) in a final concentration of 0.5 percent. This was quantitatively measured in a Beckman Model B Spectrophotometer. A somewhat similar effect was noted after the addition of 1.0 percent tryptic digest of casein. However, the values of the readings in the latter case were between those obtained for nutrient broth with and without the addition of yeast extract.

An attempt was made to cultivate *B. salmonicida* in a mineral medium to which had been added an inorganic or organic carbon source such as:

Na_2CO_3, $NaC_2H_3O_2$, glucose, sucrose, lactose, and maltose in various combinations and permutations with sources of nitrogen such as NH_4Cl, NH_4NO_3, KNO_3, $(NH_4)_2HPO_4$, $(NH_4)_2CO_3$, and asparagine. The carbon sources were employed at a final concentration of 0.5 and 1.0 percent. The nitrogen sources were used at a final concentration of 0.1 percent with the following exceptions; NH_4Cl, 0.5 percent; asparagine, 0.3 percent. The mineral base to which the various substances were added was of the following composition in milligrams per liter of double-distilled water:

TABLE 1.—*Fermentation action of* B. salmonicida

[AG = acid and gas: "..." = negative after 39 days incubation at 20° C. All materials were sterilized by filtration and incorporated into the sterile basal medium at a final concentration of one percent]

Substance	Reaction	Substance	Reaction
Monosaccharides		Polysaccharides (cont.)	
Arabinose	AG[1]	Melezitose	...
Rhamnose	...	Starch	AG[2]
Xylose	...	Inulin	...
Dextrose	AG	Dextrin	AG[2]
Fructose	AG	Glycogen	AG
Galactose	AG	Glucosides	
Mannose	AG	Salicin	AG[3]
Disaccharides		Esculin	AG[2]
Lactose	..	Amygdalin	..
Sucrose	...	Methyl glucoside	..
Maltose	AG	Alcohols	
Trehalose	...	Glycerol	...
Melibiose	...	Erythritol	...
Cellobiose	...	Adonitol	...
Polysaccharides		Mannitol	AG
Raffinose	...	Sorbitol	...
		Dulcitol	...

[1] 4 days [2] 2 days [3] 3 days

$MgSO_4$	200	K_2HPO_4	250
$FeSO_4.7H_20$	20	KH_2PO_4	250
$ZnSO_4$	0.4	NaCl	5,000
$CuSO_4$	0.4	H_3BO_3	0.4
$CoCl_2$	0.4	$Na_2MoO_4.2H_2O$	0.4
$MnSO_4.H_20$	1.0		

The pH was adjusted to 6.8 and the medium was distributed into screw-capped test tubes in 10-milliliter amounts and sterilized at 121° C. for 10 minutes.

Four strains of *B. salmonicida* (S–1, 9, 22, 23) were grown in nutrient broth for 48 hours; the cultures were then centrifuged and the supernatant broth decanted. The cells were resuspended in 0.9-percent saline, centrifuged, and again suspended in fresh saline. The above combinations of carbon and nitrogen compounds in mineral medium were then inoculated with 0.2-milliliter of saline suspensions of *B. salmonicida* and the tubes were incubated at 20° C. None of the combinations employed was found to support the growth of the microorganism after 12 days of incubation.

Another medium was then devised in which amino acids in the form of "vitamin-free," acid-hydrolyzed casein were added to the mineral base. The composition of this medium is given in Table 2. The inoculum was prepared and the tubes incubated in the manner described above. Good growth of *B. salmonicida* occurred in this medium in 24 hours and excellent growth was noted at the end of 48 hours.

TABLE 2.—*Composition of semi-synthetic medium for the cultivation of* B. salmonicida
[The pH was adjusted to 7.2 with NaOH. The medium was distributed in screw-capped test tubes in 10-milliliter quantities and autoclaved at 121° C, 10 minutes]

Constituent	Amount
Acid hydrolyzed casein ("vitamin free")[1]	50 milliliters
L-cystine	0.1 gram
Tryptophan	0.05 do.
Serine	0.10 do.
Glucose	5.0 do.
Mineral base	As formulated
Calcium pantothenate	1.0 milligram
Nicotinamide	0.05 do
Biotin	2.0 micrograms
Distilled water, to	1,000 milliliters

[1] 10-percent aqueous solution

The medium in Table 2 was further modified by substituting various amino acids for the acid-hydrolyzed casein. The composition of this medium is given in Table 3. This medium is of empirical definition and many of the components are probably not required. For example, the microorganism apparently does not require either tyrosine or phenylalanine since these

TABLE 3.—*Composition of basal medium for cultivation of* Bacterium salmonicida
[The pH was adjusted to 6.8; distilled water made up to 1 liter. Sterilized at 116° C for 10 minutes]

Constituent	Amount	Constituent	Amount
$MgSO_4$	200 milligrams	Adenine	10 milligrams
K_2HPO_4	25 do.	Guanine	10 do.
KH_2PO_4	25 do.	Uracil	10 do.
NaCl	5.0 grams	DL-alanine	500 do.
$CaCl_2$ anhydrous	50 milligrams	L-arginine.HCl	500 do.
Salts Solution[1]	1.0 milliliter	L-asparagine	500 do.
Thiamine.HCl	0.1 milligram	L-glutamic acid	1.0 gram
Nicotinic acid	1.0 do.	Glycine	500 milligrams
Nicotinamide	0.05 do.	DL-histidine.HCl	200 do.
Calcium pantothenate	1.0 do.	L-hydroxyproline	10 do.
Riboflavin	2.0 do.	DL-leucine	500 do.
Pyridoxine	2.0 do.	DL-lysine.HCl	60 do.
Pyridoxamine.2HCl	2.0 do.	DL-methionine	40 do.
Para-aminobenzoic acid	1.0 microgram	DL-proline	100 do.
Biotin	2.0 do.	DL-serine	100 do.
Choline.HCl	1.0 milligram	DL-threonine	50 do.
Inositol	1.0 do.	DL-tryptophan	50 do.
Folic acid	2.0 do.	DL-valine	50 do.
Putrescine	0.05 do.	DL-isoleucine	30 do.
B_{12}	15 micrograms	L-cystine	3.0 do.
Noble agar (Difco)	15 grams		

[1] Salts solution: $FeSO_4.7H_2O$, 5 grams; $ZnSO_4$, 0.1 gram; $CoCl_2$, 0.1 gram; $MnSO_4.H_2O$, 0.2 gram; $CuSO_4$, 0.1 gram; water to 250 milliliters

two amino acids can be withheld from the medium without any appreciable effect in the amount of growth at the end of a given period of time. Furthermore, most of the vitamins can likewise be eliminated. Additional work on the exact amino-acid requirements of *B. salmonicida* is obviously necessary.

EFFECT OF ANTIBIOTICS

The *in vitro* sensitivity of *B. salmonicida* was determined through the use of Bacto "Sensitivity disks". Several strains (S–1, 9, 14, 20) of the microorganism were grown on trypticase-yeast extract agar for 48 hours, emulsified, and then suspended in nutrient broth. Sterile cotton swabs were used to spread the microorganisms over the surface of trypticase-yeast extract agar plates. Each test plate contained disks representing three concentrations of each of the following antibiotics: dihydrostreptomycin, penicillin, terramycin, aureomycin, bacitracin, and chloromycetin. The diameter of the zones of inhibition was measured at the end of 24 hours. The data indicated that *B. salmonicida* was sensitive even to the lowest concentrations (10 micrograms per disk) of the following: chloromycetin, aureomycin, and terramycin. The microorganism was unaffected by the low and intermediate concentrations of bacitracin, dihydrostreptomycin, and penicillin. Relatively small zones of inhibition resulted when disks of the latter three antibiotics containing the highest concentration were employed (20, 10, and 10 units respectively).

PIGMENT FORMATION

B. salmonicida produces a diffusible red-brown to dark-amber pigment when grown on trypticase-yeast extract agar. The experiments of Gutsell and Snieszko (1949) indicated that this was the best medium for the demonstration of pigmentation. The same authors (1948) also pointed to the ease of a presumptive diagnosis of furunculosis in fish, based on pigmentation, through the use of such a medium.

On trypticase-yeast extract agar slants, a light pink pigment first appears in the medium at the very tip of the slant at the end of 28 to 30 hours of incubation. In 48 hours the color of the pigment changes to a red-amber and extends downward for approximately 1½ inches from the tip of the slant. At the end of 72 hours of incubation half or more of the agar slant contains a brown-amber pigment. In 96 or more hours, practically the entire agar slant is filled with a coffee-brown pigment. The latter changes to an intense amber-black after prolonged incubation. It may be of interest to note that in the very early stages of the pigmentation process, the colonies themselves are essentially unpigmented. After additional incubation, the colonies also change to a brown color.

In trypticase-yeast extract broth, pigmentation is delayed sometimes as long as 10 to 12 days. This difference was found to be due, at least in part, to the fact that on agar medium, the pH quickly changes to alkaline regions as the microorganism grows; in broth, the reverse occurs with an initial lowering of the pH value to acid regions. The latter then slowly begins to increase and at the time that a pigment forms in broth, the pH is alkaline. These observations are in accord with current concepts of melanogenesis, since an alkaline environment is an apparent prerequisite to the formation of these darkly colored products. However, it should be noted that the best pigmentation occurs at that pH at which the most luxuriant growth occurs. The present study has indicated that this value initially is approximately from 6.5 to 6.8. As a consequence of the metabolic activity of the microorganism, the pH then rapidly changes toward greater alkalinity. The importance of the direction of change of pH is further indicated by the observation that the addition of maltose delays the appearance of a pigment by as much as 24 to 48 hours. In the present study, this delay has been shown to result from the action of the microorganism on this carbohydrate to produce acids.

Oxygen is also prerequisite to pigment formation since anaerobic cultures will not pigment. Reduction in pigmentation can be obtained also by growing the microorganism in an atmosphere of approximately 10-percent CO_2 (candle jar method) or by merely tightening the caps of screw-capped culture tubes.

That the temperature of incubation is also important is indicated by the observation that progressive increases above 20 to 22° C. result in a corresponding decrease in the intensity of the pigment and at an incubation temperature at 32° C, pigmentation does not occur.

The composition of the medium is of paramount importance to pigment production. Griffin (1952) reported that a dark-amber to black pigment was produced in nutrient agar by the addition of either L-tyrosine or L-phenylalanine. That either of these two substances is the starting material for the production of a melanin-like pigment has been shown by Griffin, Snieszko, and Friddle (1952b), since a pigment is not formed in a defined medium which lacks either of these two amino acids.

Substrate concentration is also important. Progressive increases in the concentration of L-tyrosine ethyl ester up to 75-milligrams percent resulted in a corresponding increase in the intensity of the color of the pigment formed in a completely synthetic medium. Subsequent increases above this level did not result in any further visible changes in color. The addition of tyrosine ethyl ester to agar usually shortens the time necessary for the first appearance of the pigment; the time in broth is shortened by as much as 3 to 5 days. In broth, the addition of tyrosine ethel ester even in concentrations above 75-milligrams percent had no effect on the amount of growth produced as measured by a Beckman Model B spectrophotometer.

Substances other than L-phenylalanine or L-tyrosine will also act as substrates for the enzyme or enzyme systems in *B. salmonicida* concerned in the formation of a pigment. For example D-phenylalanine, glycyl-L-phenylalanine, and B-2-thienylalanine can substitute for L-phenylalanine. L-tyrosine ethyl ester, and glycyl-L-tyrosine can be substituted for L-tyrosine. The color and intensity of the resultant pigments vary according to the particular material used. To cite but one example, a bright salmon-pink color is produced through the use of B-2-thienylalanine.

CONCLUSIONS

Despite the many contradictory descriptions of *B. salmonicida,* it may be stated that on the basis of the 10 strains employed in these studies, *B. salmonicida* appears to be remarkably consistent in its general cultural and biochemical characteristics. Much of the confusion arising from the earlier descriptions of this microorganism undoubtedly reflects the use of media which varied in composition from one laboratory to the next. Today, most research workers have at their disposal media of relatively standardized composition prepared commercially by several reliable firms. As a consequence, many of the differences in observations, due primarily to variations in methods of preparation of the media have been eliminated. This lack of standard media may account, at least in part, for the discrepancies noted between the present study and reports of former years concerning the action of *B. salmonicida* on maltose.

The different statements concerning the presence or absence of a pigment in gelatin, litmus milk, and various types of fluid and solid media are now readily understandable in the light of the present study. For example, differences in the amount of either or both of the two amino acids primarily concerned in pigment production (L-phenylalanine and L-tyrosine singly or in peptide linkage with other amino acids) could readily explain the variation in observations concerning pigment formation in gelatin and milk media. Not only are quantitative differences such as those described in this report of importance; also differences in pH, content of fermentable sugars, availability of oxygen, and incubation temperature are not without influence in the formation of a pigment by *B. salmonicida.* It may also be of interest to note that some investigators have stated that occasionally some strains of *B. salmonicida* were encountered which did not have the ability to form a pigment. The present studies also have indicated that slight strain differences do exist with respect to ability to produce pigment. For example, some strains apparently require slightly larger concentrations ot tyrosine and/or phenylalanine to produce a pigment comparable to that produced by other strains in the presence of lower concentrations of either or both of these amino acids. One can therefore question the existence of all of such pigmentless strains which have been reported. Some, undoubtedly may actually be mutant strains of *B. salmonicida*—strains which have lost their abliity to produce the necessary enzyme or enzyme systems connected with the process of pigmentation. Others may represent microorganisms which require more than the average amount of the amino acids mentioned, before a visible pigment can be produced. However, until such time as these pigmentless strains have been isolated and studied, the question must remain unresolved.

The data presented in the present report may not only serve to establish what may be considered as a 'model' description of *B. salmonicida,* but may also justify a change in the taxonomic position of this microorganism from the general class, *Bacterium,* to the new genus *Aeromonas* Kluyver and Van Niel.

LITERATURE CITED

BREED, R. S., E. G. D. MURRAY, and A. P. HITCHENS
1948. Bergey's manual of determinative bacteriology, 6th Ed. Williams and Wilkins Co., Baltimore, xvi + 1,529 pp.

EMMERICH, R. und C. WEIBEL
1894. Ueber eine durch Bakterien erzeùgte Seùche unter den Forellen. Arch. für Hygiene., Bd. 21, S. 1–21.

FISTER, H. J.
1950. Manual of standardized procedures for spectrophotometric chemistry. Standard Sci. Supply Corp., New York.

GRIFFIN, P. J.
1952. Some factors influencing pigment production in *Bacterium salmonicida.* Bact. Proc., p. 53.

GRIFFIN, P. J., S. F. SNIESZKO, and S. B. FRIDDLE
1952a. A new adjuvant in the diagnosis of fish furunculosis caused by *Bacterium salmonicida.* Vet. Med., Vol. 48, pp. 280–282.
1952b. Some aspects of the biochemistry of melanin formation by *Bacterium salmonicida.* Jour. Bact. [Submitted for publication.]

GUTSELL, J. S., and S. F. SNIESZKO
1948. Furunculosis in fish; its diagnosis and treatment. Vet. Med., Vol. 43, pp. 484–486.
1949. Dosage of sulfamerazine in the treatment of furunculosis in brook trout, *Salvelinus fontinalis.* Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 82–96.

MCCRAW, B. M.
1952. Furunculosis of fish. U. S. Dept. Interior, Fish and Wildlife Serv., Special Sci. Rep.: Fish. No. 84, 87 pp.

A New Adjuvant In The Diagnosis Of Fish Furunculosis Caused By *Bacterium salmonicida*

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THE degree of effectiveness in the treatment of furunculosis in fish with sulfonamides is increased considerably by as rapid an initiation of therapy as possible. Thus one can readily recognize the importance of rapid and accurate diagnostic measures. Signs and symptoms of furunculosis are protean and occasionally even experienced fish pathologists may not be able to diagnose this disease correctly without isolating and identifying *Bacterium salmonicida,* the etiological agent. A complete bacteriological examination is a time-consuming procedure, consequently an additional aid or adjuvant to diagnosis appears desirable. The present report describes a new presumptive test for *B. salmonicida.* The test is rapid, dependable, and one which can be carried out in the field with a minimum of effort.

The first presumptive test for *B. salmonicida* was introduced by Gutsell and Snieszko†. In this test, a special solid and semisolid medium was inoculated with material removed from the kidney of the infected fish. The development of a brownish-red pigment within two to three days in the solid medium and the absence of spreading growth in the semisolid medium within 24 hours (indicating non-motility), was considered as positive presumptive evidence for the presence of *B. salmonicida.* However, in this test at least 48 hours must be allowed before any conclusive assertions can be made as to incipient coloration or pigmentation and nuances of intensity. Indeed, lack of pigmentation at the end of this time prompts one to withhold even a presumptive statement as to the absence of the disease in deference to the possibility that pigmentation will occur in the medium after a more extended incubation time.

Indication of a more rapid presumptive diagnostic method resulted from observation that coloration or pigmentation of the medium upon which various strains of *B. salmonicida* are grown is the probable result of oxidation of tyrosine or phenylalanine occurring at some point in metabolism of the organism (Griffin, 1952)††. This finding implied that the enzyme tyrosinase was involved in the pigmentation process. Because of this, use of paraphenylenediamine as a test reagent was prompted since the latter substance undergoes a color change in the presence of a certain group of enzymes of which tyrosinase is a member.

Usefulness of paraphenylenediamine as an aid in diagnosis of furunculosis in fish was therefore investigated. A 1% aqueous solution of paraphenylenediamine was freshly prepared and stored in a refrigerator. Twenty-five strains of *B. salmonicida* were grown on trypticase-yeast extract agar.

Composition of medium for *Bacterium salmonicida*: trypticase, 10 gm.; yeast extract, 5 gm.; NaCl, 2.5 gm.; distilled H_2O, 1,000 ml.; pH adjusted to 6.8 with NaOH and sterilized in the autoclave.

All existing data indicate that this is the preferred medium to be used in cultivation of *B. salmonicida* (Gutsell and Snieszko). No evidence of pigmentation of the medium was noted at the end of 18 to 24 hours' incubation time at 22 C. One-half ml. of the paraphenylenediamine test reagent was applied directly to the colonies of *B. salmonicida* growing on the surface of the slants. Tubes were quickly tipped and rotated in such a manner as to allow complete contact of the reagent with all of the growth. Tubes were then placed in test tube racks for further observation. Within 45 to 90 seconds, the surface growth of all strains of *B. salmonicida* tested began to exhibit a color change from that of colorless to a distinct purple. The latter color increased in intensity and within three minutes the colonies turned a deep purple-black. Only the colonies and not the surrounding medium changed color. However, in time a color does develop in the surrounding medium due to diffusion of the reagent.

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†*Trans. Am. Fish. Soc.,* 76:82, 1949.

††*Bact. Proc.,* 1952, p. 53.

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This test was then employed against 56 cultures of bacteria which had been isolated from material taken from various organs and lesions of diseased and dead fish. The identity of some of these microorganisms was known and others were either of unknown genera or species or both; however none of these cultures was characterized as *B. salmonicida*. These microorganisms represented isolates made from fish found in widely different sections of the United States. Cultures of these microorganisms grown for 18 to 24 hours, were tested with the reagent in the manner described. Results are recorded in table 1, an inspection of which indicates that of the 56 cultures tested, the colonies of 31 remained colorless after application of the test reagent and the colonies of 25 cultures did undergo the color change as described for *B. salmonicidia* in a population suspect of furunculosis. were then examined for motility and without exception it was found that these microorganisms were motile. This observation thus served to distinguish them from *B. salmonicida* since the latter is non-motile.

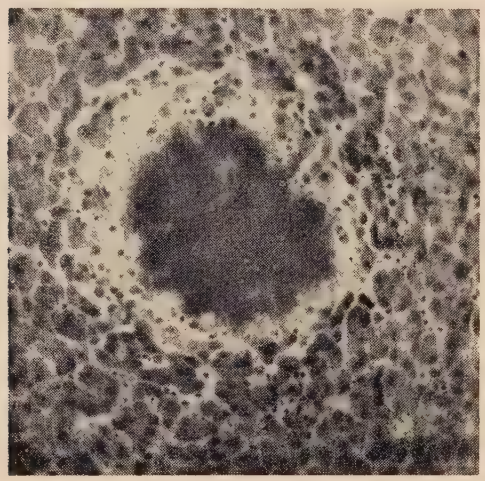
Fig. 1. Cross section of a furuncle in brook trout. Note the bacteria. Magnification 1,000x.

The usefulness of this new test seems apparent, for within 18 to 24 hours or sooner, provided sufficient growth occurs, one can supply a ready answer to the question of the presumed presence or absence of *B. salmonicida* in a population suspect of furunculosis. Failure of the colonies of a particular culture to undergo the described color change quickly eliminates the possibility of presence of this organism. This in itself seems highly advantageous. Those cultures in which the colonies do exhibit a positive color test (*i.e.*, turn a purple-black color after application of paraphenylenediamine) may be easily checked for the presence of motile organisms. Existence of the latter condition then serves to exclude the presence of *B. salmonicida*. The test may offer an additional advantage in those cases of a mixed culture in that it will help to point out those colonies which could be *B. salmonicida* growing among colonies of other types of microorganisms.

It may be advisable to note that although the test had been 100% diagnostic in the writers' hands, this fact in itself does not exclude the probable existence of microorganisms isolated from diseased or dead fish which are not *B. salmonicida* and yet may exhibit a positive color test and which are also non-motile. Another condition with which one may be confronted is the possibility of a mixed culture composed of *B. salmonicida* and other microorganisms which will also exhibit a positive color test. In the event of such a condition, one would of course, be forced to rely on both colonial differences and production of the characteristic red-brown pigment. However, if the present report is a reflection of the general trend, then this new method should retain a measurable degree of value in diagnosis.

In those cases of cultures which are obviously mixed, *i.e.*, contain more than one colonial type, it is advisable to apply the test reagent to the lower half of the surface growth by means of a pipette. Should one or more types of colonies change color, one may then isolate similar colonies from the upper half of the slant and examine this material for motile organisms. This suggestion also accounts for the fact that one may wish to subculture the types undergoing the color change in order to

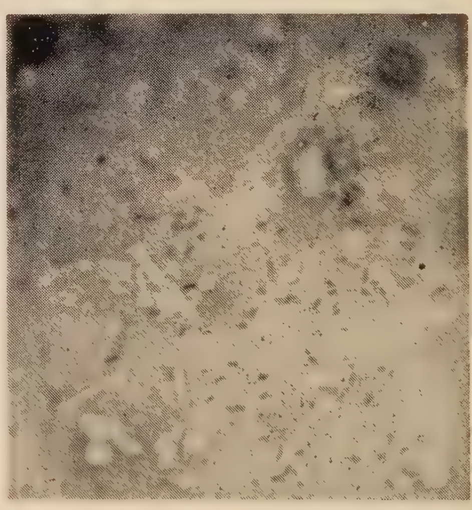
Fig. 2. Stained smear from the kidney of the infected trout. Note the bacteria. Magnification 1,000x.

obtain them in pure culture. An alternative procedure is to select and isolate a colony in the process of changing color. This material may then be used for subculturing. The test reagent will not kill most organisms immediately and the period of time in which viable organisms are still present is sufficient to allow for such additional subculturing methods as may be desired.

TABLE 1. Results of Paraphenylenediamine — Motility Tests

Organism	Number Tested	Para-pheny. Test	Motility
B. salmonicida	25	+	—
Group I	31	—	±*
Group II	25	+	+

*Motile and non-motile.

The test reagent remains stable for at least six weeks if maintained at refrigeration temperature and hence the necessity of frequent preparation is eliminated. Convenience and rapidity of the method described in this report are reflected by the time necessary to complete the entire procedure, approximately five minutes.

Addendum

After preparation of the original manuscript, some additional information concerning the efficacy of this method, as applied under practical field conditions, came to the attention of the authors. Mr. Paul E. Giguere of Cornell University consented to include the new test as a part of his investigations of furunculosis in fish taken from wild waters. His data were most gratifying and are presented below:

"A total of 156 cultures were subjected to the color test. These represented specimens taken from 73 fish. One hundred and thirty-three of these did not give a positive test. Sixteen (representing 13 fish) gave a positive test, but were motile. Seven gave a positive test (representing seven different fish), were non-motile, and were *B. salmonicida.*"

These data represent the first practical application of this test in the field and indicate that the proposed method is of definite value.

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PIGMENT FORMATION BY BACTERIUM SALMONICIDA

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An extensive literature exists concerning the role of tyrosine and tyrosinase in the formation of melano-pigments. This interest reflects the widespread distribution of the enzyme and the conspicuousness of such pigments in man, animals, and plants. Several comprehensive reviews exist on these pigments and the various factors which influence their formation (Raper, 1928; Lerner and Fitzpatrick, 1950; Dawson and Tarpley, 1951). Much of the emphasis has been directed to the metabolism of tyrosine, an amino acid which plays an important role in melano-pigmentation. The formation of these darkly colored products from their precursors is a complex phenomenon, and detailed information concerning their identity and the sequence of chemical reactions which transform tyrosine to pigmented products is also incomplete.

Bacterium salmonicida, a pathogen of salmonoid fishes, produces a dark amber to brown-black pigment especially when grown on a tryptic digest of casein-yeast extract medium (Gutsell and Snieszko, 1949). Griffin (1952) reported that only a light brown color was produced in nutrient agar and that the addition of L-phenylalanine or L-tyrosine resulted in the formation of a deep amber pigment. The present report deals largely with the effect of compounds structurally related to tyrosine and phenylalanine on pigment formation. These studies suggest that *B. salmonicida* may be a convenient tool for investigating the nature and formation of pigments derived from phenylalanine and tyrosine.

METHODS

Culture and inoculum. Four strains of *B. salmonicida* were maintained at 6 C on a stock medium of the following percentage composition: trypticase 1.0, yeast extract (Difco) 0.5, NaCl 0.25, agar 1.5. All inoculations for the varied media employed in this study were made by utilizing the cells obtained from a second 24 hour subculture of the microorganism grown on the stock medium or basal medium (*vide infra*). The incubation temperature was 20 to 22 C.

Basal medium. The composition of the medium used for the investigations of substances structurally related to tyrosine or phenylalanine is presented in table 1. Slightly better growth occurred after the addition of 0.1 ml of a 10 per cent aqueous solution of autoclaved yeast extract to 10 ml of this medium. In experiments on compounds related to L-tyrosine or L-phenylalanine the basal medium as defined in table 1, with and without the yeast extract supplement, was used.

The effect of substituting compounds similar in structure to tyrosine or phenylalanine was noted by the presence or absence of a brown or amber-black pigment in the agar medium. The various additions were dissolved in distilled water, whenever possible the pH was adjusted from 6.5 to 6.8, and sterilization was accomplished by passage through Coors porcelain filters.

RESULTS

Effect of oxygen on pigment. Under aerobic conditions on stock medium slants, pigmentation usually appears after 28 to 30 hours' incubation at 22 C. At this time a very faint pinkish coloration can be detected in the medium at the extreme tip of the slant. A corresponding increase in the extent and intensity of coloration in the medium follows. Within 48 hours, the color changes from pink to red-amber and extends downward in the agar to approximately one-half of the slanted portion of the medium. At 72 hours, three-quarters of the tube contents is brown-amber in color, and at 96 hours or later substantially the color of the entire slant is deep coffee brown to black. Early in the pigmentation process, the colonies on the surface of the slant remain nearly colorless; after continued incubation the surface growth also becomes light brown.

Williamson (1928) reported that *B. salmonicida* does not produce pigment under anaerobic conditions. This was confirmed in our experiments in which oxygen was removed by using *Serratia marcescens* (Snieszko, 1930) or by utilizing a modification of the alkaline pyrogallol system of pray (1930). Growth under approximately 10 per cent CO_2 (candle-jar method) curtails pigment formation, and practically complete inhibition of pigmentation was obtained merely by tightening the tops of the screw-capped tubes in which the cultures were grown.

Time and temperature. Excellent growth occurred in 18 hours on stock medium slants; however, the formation of a visible pigment in the medium usually required an additional 10 to 12 hour incubation period. This lag in the appearance of pigment may be analogous to the "induction period" described by other investigators for tyrosine-tyrosinase reactions in the presence of oxygen. Under the latter circumstances, there frequently is a lag period before the oxidation begins, as followed by O_2 uptake measurements. Experiments were initiated to determine whether the addition of 3,4 dihydroxyphenylalanine (dopa) or catechol accelerated pigment production by *B. salmonicida.* In these tests, 1.0, 0.1, 0.01, and 0.001 mg of dopa and catechol were added to tubes containing 10 ml of stock agar. At the end of 24 hours of incubation, growth was absent in those tubes containing 1.0 mg of catechol and growth was poor in the 1.0 mg dopa tubes. Growth occurred at all concentrations after prolonged incubation; however, the pigment was not formed more rapidly in any of the tubes containing dopa or catechol when compared with stock agar controls.

When 1 per cent "tween 40" was added to stock agar, pigmentation was delayed by as much as 4 to 6 days. A concentration of 0.1 per cent "tween 40" reduced the amount normally formed during the early stages of the pigment process, but lower levels were without effect. Lerner and Fitzpatrick (1950) previously showed that "tween 20" prolongs the induction period of the tyrosine-tyrosinase reaction.

Incubation at temperatures above 22 C reduced the intensity of pigmentation. At 32 C excellent growth occurred but a pigment did not appear. Pigment was not produced even after prolonged incubation when the microorganism was grown on stock agar slants at 22 C for 18 hours (approximately 10 to 12 hours before the usual pigmentation time) and then heated to 32 C in a water bath for 5 minutes and incubated at this elevated temperature. However, if the

TABLE 1

Basal medium for cultivation of Bacterium salmonicida

$MgSO_4$	200	mg	Adenine	10	mg
K_2HPO_4	25	mg	Guanine	10	mg
KH_2PO_4	25	mg	Uracil	10	mg
NaCl	5.0	g	DL-Alanine	500	mg
$CaCl_2$ (anhydrous)	50	mg	L-Arginine·HCl	500	mg
Salts solution*	1.0	ml	L-Asparagine	500	mg
Thiamin·HCl	0.1	mg	L-Glutamic acid·HCl	1.0	g
Nicotinic acid	1.0	mg	Glycine	500	mg
Nicotinamide	0.05	mg	DL-Histidine·HCl	200	mg
Calcium pantothenate	1.0	mg	L-Hydroxyproline	10	mg
Riboflavin	2.0	mg	DL-Leucine	500	mg
Pyridoxine·HCl	2.0	mg	DL-Lysine·HCl	60	mg
Pyridoxamine·2HCl	2.0	mg	DL-Methionine	40	mg
p-Aminobenzoic acid	1.0	µg	DL-Proline	100	mg
Biotin	2.0	µg	DL-Serine	100	mg
Choline·HCl	1.0	mg	DL-Threonine	50	mg
Inositol	1.0	mg	DL-Tryptophan	50	mg
Folic acid	2.0	mg	DL-Valine	50	mg
Putrescine	0.05	mg	DL-Isoleucine	30	mg
Vitamin B_{12}	15	µg	L-Cystine	3.0	mg
Noble agar (Difco)	15	g			

pH adjusted to 6.8; distilled water to 1,000 ml. Sterilized at 116 C for 10 min.

* Salts solution: $FeSO_4 \cdot 7H_2O$, 5 g; $ZnSO_4$, 0.1 g; $CoCl_2$, 0.1 g; $MnSO_4 \cdot H_2O$, 0.2 g; $CuSO_4$, 0.1 g; water to 250 ml.

cultures were placed at 32 C approximately 2 hours prior to the time at which pigmentation begins, a light brown coloration formed at the end of 96 hours. When the microorganism was incubated at 22 C until a very slight amount of pink coloration appeared at the tip of the slant and the cultures then heated and transferred to the higher temperature, pigmentation continued and at the end of 96 hours, over three-quarters of the slanted portion of the agar became dark brown. In general, after the initial formation of a pigment, the longer the incubation period at the lower temperature the more pronounced the pigmentation process was when the tubes were transferred to the higher temperature for further incubation. If the incubation was continued at 22 C until approximately the top 2.5 cm of the slant contained a red pigment, then pigment formation at 32 C was comparable to that which was produced at the lower temperature. The same process occurred at 37 C even though *B. salmonicida* did not grow at this temperature.

Pigmentation progressed in essentially the same manner as described above at all temperatures when chloroform was added to the surface of those slants in which pigmentation had begun. Loopfuls of cells from these cultures were transferred to fresh broth, but growth did not occur. Cultures which had been grown at 22 C until a pigment appeared were heated in a water bath at 70 C for 15 minutes, quickly cooled to and incubated at temperatures of 22, 32, and 37 C. Within 12 hours a red-amber color developed which was more intense than that present in unheated controls maintained at 22 C. The initial pink or light red color also had changed to a purple-brown immediately after heating.

Lerner and Fitzpatrick (1950) indicated that the rate of enzymatic oxidation of tyrosine to melanin is more rapid above 30 C. In contrast, actively growing cells of *B. salmonicida* can initiate pigmentation at 22 C but not at 32 C. Recently Horowitz and Shen (1952) reported that tyrosinase production in *Neurospora* also is dependent on the temperature of cultivation and that at 35 C the cultures are practically devoid of enzymatic activity.

Cultures of *B. salmonicida* were incubated at 22 and at 32 C until a pigment formed in the upper half of the slant in those cultures held at 22 C. Some of the cultures grown at the higher temperature then were transferred to the lower temperature and incubated for a suitable period A pigment eventually was formed in the lowe half of both sets of cultures grown at 22 C bu was absent in the upper half of those slant originally incubated at 32 C. Transfers from th higher to the lower temperature at various increased time intervals resulted in a correspondin decrease of pigment in the upper portions of th slanted surface. When maintained at 32 C unti complete pigmentation occurred in the contro tubes at the lower temperature, a pigment di not develop when the cultures were transferre from 32 to 22 C. One possible explanation of thes observations is that the enzyme or enzyme syste is formed at the higher temperature, but formation of the initial red pigment is either blocke or, alternatively, another path is in operatio which leads to colorless products.

The increase in pigment at elevated temperatures is not a result of simple diffusion of th small amount of colored products originall formed at 22 C since the intensity and extent o pigment are so much greater at higher temperatures. This view accords with the fact that whe cultures which contain the initial pigment ar treated with formaldehyde, the pigmentatio process stops and the original color present a the time of the addition of formaldehyde remain unaltered in intensity and extent at any temperature. One also could interpret the data t mean that the elevated temperatures accelerat an autocatalytic oxidation of precursor compounds previously formed only at the lower temperature. Once formed, no pigment forming enzyme need be present at this stage as the CHCl suggests. Formaldehyde may inhibit this reactio by binding and preventing the autoxidation reaction. The formaldehyde treated cultures wer found to be convenient controls and were use to compare the changes in pigmentation with th color of the originals.

Woiwod and Linggood (1949) reported th possible combination of tyrosine with formaldehyde as indicated from qualitative difference between chromatograms of acid hydrolyzate highly purified diphtheria toxin and toxoi Tyrosine was present in the chromatogram toxin but not in toxoid. Fraenkel-Conrat *et a* (1947) noted that the indole groups of gramicidi react rapidly with formaldehyde in alkaline solution, the formaldehyde bound being equivale to the tryptophan content. Should the red produ nitially formed by *B. salmonicida* prove to be an ndole derivative (like dopachrome)[1] then a imilar explanation might hold for the formaldeyde inhibition of pigment production by *B. almonicida*.

Effect of pH. Although *B. salmonicida* proluces pigment in stock agar at any pH allowing rowth (approximately pH 5.5 to 8.5), pigment ormed much sooner when the organism was rown in a medium adjusted initially at pH 6.5 to 6.8.

In broth cultures, a pigment develops at the surface only after approximately 10 to 12 days of incubation. An important factor contributing to the much slower pigment formation in broth as compared to agar is that in agar the pH rapidly changes within 24 hours from pH 6.7 to about 7.4, whereas in broth the pH change is from 6.7 to 6.3. At the end of 7 to 8 days of incubation the pH in broth usually rises to about 6.8, and at the time of pigmentation the reaction is alkaline.

In stock agar with 0.5 per cent maltose added, the onset of pigmentation is delayed by an additional 24 to 48 hours. This observation also points to the sensitivity to pH of the medium of pigment formation by *B. salmonicida*. At an initial pH of 7.0 with maltose added, the pH becomes acid. Without maltose, at 22 or 32 C, the pH quickly becomes alkaline, and at the time of incipient pigment production the first 2.5 cm of the slant containing the pigment is invariably pH 7.6 to 7.7. The alkalinity induced by growing cells of *B. salmonicida* appears to depend, at least in part, on NH_3 formation.

A micro-diffusion method was used to determine ammonia-N quantitatively. Several stock agar slants with and without 0.5 per cent maltose were inoculated and incubated in the manner described. At 8 hour intervals, one gram samples were cut away from the top portions of the agar slants, triturated, and diluted to 50 ml with distilled water. Two ml aliquots of the suspensions were transferred to the outer compartment of Conway units, and the procedure described by Fister (1950) then was followed. Toluene treated samples, prepared at the time of inoculation, served as the reagent blank and pH control. Readings were made in a Beckman Model B spectrophotometer at 625 mμ on samples contained in 10 mm matched cuvettes. Only data for one experiment with strain S-14 are presented in figure 1 as similar results were obtained with another strain and in repeat tests. Although at up to 40 hours' incubation there is some suppression of ammonia formation in maltose media, the amount of ammonia-N formed parallels that formed in the carbohydrate-free medium. This was unexpected on the basis of earlier observations from qualitative tests for NH_3 (Nessler's reagent). The lower pH values obtained in the presence of this carbohydrate may be explained, in part, by the formation of acids. It has been noted by Gale (1951) that in general, in the presence of fermentable carbohydrate, the liberation of ammonia usually is suppressed and the formation of deaminase is diminished markedly. In cultures of *B. salmonicida*, pigmentation correlated with pH. Other than the influence of NH_3 production on pH values, it appears likely that the pigmented products are not necessarily a

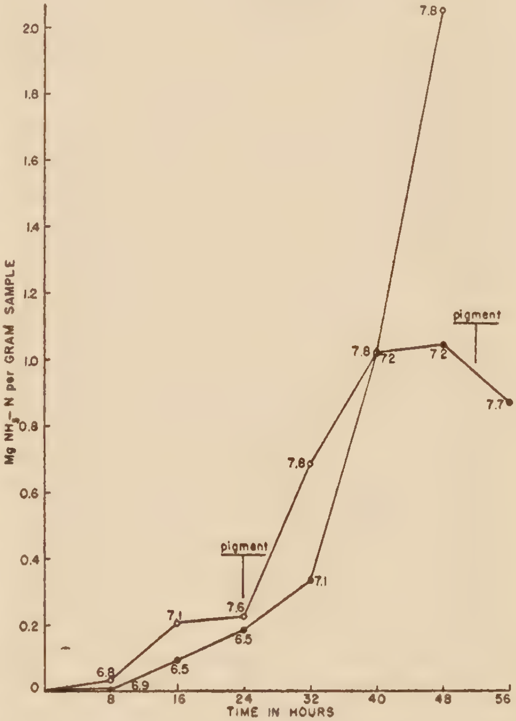

Figure 1. Relation of NH_3-N, pH, and time of pigment formation by *Bacterium salmonicida*, strain S-14. Open circles represent data obtained from media without maltose; filled circles, with maltose. Figures on the curves represent pH values of samples.

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[1] Term suggested by Dr. A. B. Lerner. *Private communication.*

consequence of the deamination of amino acids such as tyrosine or phenylalanine since the intensified alkaline reaction also occurs in basal media devoid of either amino acid and subsequent sections of this paper present data indicating that the corresponding keto acids are not pigment formers.

Effect of compounds structurally related to tyrosine and phenylalanine. Since *B. salmonicida* acting on either L-phenylalanine or L-tyrosine gave rise to a blackened pigment, various substances which contained groups similar to those in tyrosine and phenylalanine were substituted in the basal medium to give a final concentration of at least 40 mg per cent.[2] Control tubes which contained similar concentrations of either L-phenylalanine or L-tyrosine were included as pigment controls. As noted earlier, either enantiomorph of phenylalanine is active in the pigment process; however, the natural isomer yields a darker pigment. L-Phenylalanine in peptide linkage with glycine (glycyl-L-phenylalanine) yielded a pigment which was even darker than that formed with L-phenylalanine itself. The color formed by substituting the analog β-2-thienylalanine was of particular interest. This compound alteration has the ring carbon atoms 2 and 3 of phenylalanine replaced by a sulfur atom. The color, a very bright salmon pink, formed throughout the medium and was reminiscent of the initial stages of the pigmentation process in stock agar in that the first visible color formed at the very tip of the slant is pink or salmon. Cyclohexyl-DL-alanine, phenylpyruvic acid, N-acetyl-L-phenylalanine, DL-β-phenyllactic acid, β-phenylserine and DL-mandelic acid were inactive. That the alanine side chain may be of prime importance in the pigmentation process is suggested by the absence of pigment "activity" by those compounds in which the amino group is missing or which contain a substituent for one of the hydrogen atoms of the α amino group or of the β carbon atom.

Curiously, when a pigment was formed in the basal medium which contained tyrosine or tyrosine ethyl ester, the intensity of the color was never as pronounced as that which formed in stock agar. Increasing the concentration of tyrosine ethyl ester from 10 to 75 mg per cent resulted in a corresponding increase in the depth of the color formed in the medium. Concentrations above 75 mg per cent were without apparent effect.

When glycyl-L-tyrosine was added to the basal medium, an intense brown-black color developed which resembled the pigment which was formed in stock agar. Additional tests, which included glycine alone and in combination with L-tyrosine, indicated that the addition of glycine did not increase the intensity of the pigment over that observed in the basal medium with the addition of only L-tyrosine. Paredrine, tyramine, N-formyl-L-tyrosine, N-acetyl-L-tyrosine, N-(p-hydroxyphenyl) glycine, p-hydroxyphenylacetic acid, p-hydroxyphenylpropionic acid, p-hydroxyphenylpyruvic acid, 3-amino-L-tyrosine, 3-nitro-L-tyrosine, 3-fluoro-L-tyrosine, diiodotyrosine, and 3,4-dichloro-β-phenyllactic acid were inactive as substituents for tyrosine. Again, compounds in which a hydrogen atom of the amino group was substituted were inactive in the pigmentation process; this suggests that the activity of the dipeptide may be a result of cleavage of the peptide bond. The results of these tests also indicate that removal of the carboxyl group (tyramine), replacement of this group with a methyl group (paredrine), or the presence of certain substituents in the 3 or 3,5 position in the ring results in "inactivity". Tryptophan, histidine, alanine, glycine, proline, hydroxyproline, and indole-3-acetic acid also were tested and proved inactive. A light brown color developed in the medium containing p-hydroxyphenylpyruvic acid after several days; however, uninoculated control tubes made alkaline with NaOH also developed essentially the same color. 3,4-Dihydroxyphenylalanine also was tested but its autoxidation led to equivocal results.

The literature indicates that the enzyme tyrosinase, obtained particularly from various plants and lower animals, does not show a high degree of substrate specificity. A number of monohydric and polyhydric phenols (e.g., phenol and catechol) are oxidized by such enzymes. The following substances, at levels of 10, 20, and 40 mg per cent, were tested for their "pigment activity" when incorporated in basal media upon which *B. salmonicida* was grown: phenol, p-cresol, m-cresol, o-cresol, and catechol. The higher concentrations retarded growth to some extent, and under no circumstance did the characteristic amber-black pigment form. Some darkening of the medium occurred in tubes containing catechol; however, the same condition developed in control tubes which had been adjusted to pH 7.6.

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[2] Cyclohexyl-DL-alanine was used at a concentration of only 20 mg per cent because of limited supply of substrate.

DISCUSSION

Tyrosinase is distributed widely in various animals and plants, including some microorganisms (Clark and Smith, 1939; Klykov, 1945). The conditions surrounding the formation of the darkly colored products noted in the present report are remarkably similar to those essential for pigment production in *Azotobacter chroococcum* as described by Ungerer (1934). The action on tyrosine by intact cells of *B. salmonicida* seems of particular interest in that the sequence of visible color change from pink or red through brown to amber-black parallels the color changes described for melanin formation in mammals.

Raper and Wormall (1923) and Raper and Speakman (1926), using tyrosinase preparations obtained from potato juice and mealworms, demonstrated that when tyrosine is oxidized by tyrosinase the first visible change is the formation of a red pigment (dopachrome). This compound undergoes a decarboxylative rearrangement, and apparently the reaction is base catalyzed (Mason and Wright, 1949).

The formation of pigment in *B. salmonicida* always is accompanied by a shift in the reaction of the medium to the alkaline side. Once a small amount of pigment is formed in the medium by *B. salmonicida* when grown at 22 C, pigment production continues at 32, 37, or even after heating to 70 C for 15 min. It appears that once a sufficient quantity of precursor compounds is formed at 22 C, the remaining steps of the pigmentation process are a consequence of autocatalytic oxidation reactions.

A deamination of phenylalanine or tyrosine may not be requisite to the formation by *B. salmonicida* of pigmented products. Melanopigments usually contain nitrogen, and the deamination of either or both of these amino acids obviously would lead to a nonmelanin product unless the product formed is like homogentisic acid. Additional suggestive evidence is that the corresponding keto acids are not active in pigmentation. N-substitution likewise prevented pigment formation, perhaps preventing oxidation to dopa analogues or ring closure.

The conversion of phenylalanine to tyrosine has been demonstrated repeatedly (Moss and Schoenheimer, 1940; Bernheim and Bernheim, 1944; Lien and Greenberg, 1952; Udenfriend and Cooper, 1952). The present data indicate that the addition of either L-tyrosine or L-phenylalanine to the basal medium results in pigment production; phenylalanine cultures show delayed pigmentation, and the color produced is not as intense as with tyrosine. Since either amino acid is active in pigmentation, it seems reasonable to suggest that phenylalanine is first converted to tyrosine, and delay in this conversion might account for the delayed pigmentation noted in phenylalanine cultures. But until such a conversion actually is demonstrated, the possibility of alternate pathways to pigmented end products must be considered: in *Escherichia coli* (Simmonds *et al.*, 1947; Davis, 1950) and in yeast (Gilvarg and Bloch, 1951) independent routes of phenylalanine and tyrosine synthesis occur and phenylalanine apparently is not converted to tyrosine.

The tyrosinases of plants and lower animals appear less specific towards substrate than is mammalian tyrosinase. The results with *B. salmonicida* were obtained with intact cells and may well have been influenced by permeability factors. However, the limited substrate specificity observed in these studies does parallel in many respects the data with mammalian enzyme systems (Lerner *et al.*, 1951).

The utilization of *B. salmonicida* offers promise for further studies of pigment formation since one of the chief difficulties hindering research in this field has been the absence of a convenient experimental object. Melano-pigments from animal sources are difficult to isolate and to purify because of limited solubility and close binding with tissue protein; *B. salmonicida*, grown on a synthetic medium, seems of value for such studies. *B. salmonicida* also may be a useful source of the enzymes involved in converting phenylalanine and tyrosine to pigmented end products.

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SUMMARY

Some factors determining the production of a melano-pigment by *Bacterium salmonicida* were investigated. Oxygen, hydrogen ion concentration, temperature, and amount of substrate were found to be important in pigment formation. In the absence of tyrosine and phenylalanine, pigmentation of the medium did not occur. The addition of either glycyl-L-phenylalanine, L-phenylalanine, or D-phenylalanine resulted in the production of a brown or amber-to-black pigment. A bright salmon pink color developed when β-2-thienylalanine was tested.

Compounds which contained an acetyl or chloracetyl substituent in place of a hydrogen atom of the α amino group, or a hydroxyl group in place of a hydrogen atom of the β carbon atom in the alanine side chain of phenylalanine were inactive. Saturation of the benzene ring also produced an inactive substance. Glycyl-L-tyrosine, L-tyrosine, and L-tyrosine ethyl ester were chromogenic. Substitution of the hydrogen atom of the α amino or the carboxyl group of the alanine side chain of tyrosine and substituents in the 3 position on the benzene ring yielded inactive compounds. *B. salmonicida* is proposed as a useful tool in studies of pigmented products from phenylalanine and tyrosine.

REFERENCES

BERNHEIM, M. L. C., AND BERNHEIM, F. 1944 The production of a hydroxyphenyl compound from L-phenylalanine incubated with liver slices. J. Biol. Chem., **152**, 481.

CLARK, F. E., AND SMITH, N. R. 1939. Cultural requirements for the production of black pigments by bacilli. J. Bact., **37**, 277–284.

DAVIS, B. D. 1950 Studies on nutritionally deficient bacterial mutants isolated by means of penicillin. Experientia, **6**, 41–50.

DAWSON, C. R., AND TARPLEY, W. B. 1951 Copper oxidases. In *The enzymes*, edited by J. B. Sumner and K. Myrbäck. Vol. 2, Part 1, 454–498. Academic Press, N. Y.

FISTER, H. J. 1950 *Manual of standardized procedures for spectrophotometric chemistry.* Standard Scientific Supply Corporation, New York.

FRAENKEL-CONRAT, H., BRANDON, B. A., AND OLCOTT, H. S. 1947 The reaction of formaldehyde with proteins. IV. Participation of indole groups. Gramicidin. J. Biol. Chem., **168**, 99–118.

GALE, E. F. 1951 *The chemical activities of bacteria*, 3rd ed. Academic Press, Inc., New York.

GILVARG, C., AND BLOCH, K. 1951 Synthesis of phenylalanine and tyrosine in yeast. Federation Proc., **10**, 189–190.

GRIFFIN, P. J. 1952 Some factors influencing pigment production in *Bacterium salmonicida.* Bact. Proc., **1952**, 53.

GUTSELL, J. S., AND SNIESZKO, S. F. 1949. Dosage of sulfamerazine in the treatment of furunculosis in brook trout, *Salvelinus fontinalis.* Trans. Am. Fisheries Soc., 1946, **76**, 82–96.

HOROWITZ, N. H., AND SHEN, SAN-CHIUN 1952 *Neurospora* tyrosinase. J. Biol. Chem., **197**, 513–520.

KLYKOV, A. P. 1945 Tyrosinase enzyme in the causative agent of the black bacteriosis of cereals. Compt. rend. acad. sci. U.R.S.S., **47**, 597.

LERNER, A. B., AND FITZPATRICK, T. B. 1950 Biochemistry of melanin formation. Physiol. Revs., **30**, 91–126.

LERNER, A. B., FITZPATRICK, T. B., CALKINS, E., AND SUMMERSON, W. H. 1951 Mammalian tyrosinase. Action on substances structurally related to tyrosine. J. Biol. Chem., **191**, 799–806.

LIEN, O. G., JR., AND GREENBERG, D. M. 1952 Chromatographic studies on the interconversion of amino acids. J. Biol. Chem., **195**, 637–644.

MASON, H. S., AND WRIGHT, C. I. 1949 The chemistry of melanin. V. Oxidation of dihydroxyphenylalanine by tyrosinase. J. Biol. Chem., **180**, 235–247.

MOSS, A. R., AND SCHOENHEIMER, R. 1940 The conversion of phenylalanine to tyrosine in normal rats. J. Biol. Chem., **135**, 415–429.

RAPER, H. S. 1928 The aerobic oxidases. Physiol. Revs., **8**, 245–282.

RAPER, H. S., AND SPEAKMAN, H. B. 1926 The tyrosinase-tyrosine reaction. IV. Note on the identity of tyrosinase from different sources. Biochem. J., **20**, 69–72.

RAPER, H. S., AND WORMALL, A. 1923 The tyrosinase-tyrosine reaction. Biochem. J., **17**, 454–469.

SIMMONDS, S., TATUM, E. L., AND FRUTON, J. S. 1947 The utilization of phenylalanine and tyrosine derivatives by mutant strains of *Escherichia coli.* J. Biol. Chem., **169**, 91–101.

SNIESZKO, S. F. 1930 The growth of anaerobic bacteria in petri dish cultures. Zentr. Bakt. Parasitenk., II Abt., **82,** 110–111.

SPRAY, R. S. 1930 An improved anaerobic culture dish. J. Lab. Clin. Med., **16,** 203–206.

UDENFRIEND, S., AND COOPER, J. R. 1952 The enzymatic conversion of phenylalanine to tyrosine. J. Biol. Chem., **194,** 503–511.

UNGERER, E. 1934 Über die Entstehung des Pigmentes von *Azotobacter chroococcum.* Z. Pflanzenernähr. Düng. u. Bodenk., A., **36,** 287–290.

WILLIAMSON, I. J. F. 1928 Furunculosis of the *Salmonidae.* Fishery board for Scotland. Salmon fisheries, **5,** 1–17.

WOIWOD, A. J., AND LINGGOOD, F. V. 1949 Amino acid constitution of diphtheria toxin and toxoid. Nature, **163,** 218–219.

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GONYAULAX MONILATA, SP. NOV., THE CAUSATIVE DINOFLAGELLATE OF A RED TIDE ON THE EAST COAST OF FLORIDA IN AUGUST–SEPTEMBER, 1951

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In late August, 1951, the staff of the Red Tide Investigation, U. S. Fish and Wildlife Service, Sarasota, Florida, was notified of a fish-kill and discoloration of the water of the Indian River, a marine lagoon on the East coast of Florida. Preliminary examination showed that the discoloration was caused by large numbers of dinoflagellates but that no great quantity of fish were killed. A temporary laboratory was established in Melbourne, Florida for the purpose of studying this "red tide."[1]

Analysis of the chemical and biological samples and the bearing of these data on the problem of more extensive and destructive red tides will be reported in a later paper.

Gonyaulax monilata, sp. nov.

DIAGNOSIS. A small species that forms chains up to forty cells in length (Figure 2.); the plate pattern is 4', Oa, 6'', 6, 6''', 1p, 1''''; theca minutely punctate, with no spines or lists; length 37 μ (24.1 to 51.6 μ), transdiameter 57 μ (37.8 to 75.7 μ); in coastal plankton of Florida.

DESCRIPTION. *Gonyaulax monilata* is sub-spherical, flattened anteroposteriorly, the length being 0.6–0.8 times the transdiameter. A very slight dorsoventral flattening makes the dorsoventral diameter 0.8–0.9 times the transdiameter. The epitheca is slightly longer than the hypotheca due to the convexity of the apex and the concavity of the antapex.

The girdle is subequatorial, descending and displaced approximately one girdle width, with no overhang, deeply impressed and composed of six plates.

The ventral area is narrow anteriorly, widening posteriorly and is slightly impressed into the hypotheca, thus forming most of the longitudinal furrow. The ventral area is composed of four platelets (Figure 1), one anterior (ap), two intermediate (ip), and one posterior (pp). The posterior plate of the ventral area is rhomboid and is marked by six to ten radial lines (Figure 5). This plate is impressed about one-half girdle width into the hypotheca and contains the posterior attachment pore (p) on a small prominence in the center of the plate.

The plate formula is 4', Oa, 6'', 6, 6''', 1p, 1''''. In addition there is the closing plate of the apex (cl. pl., Figure 4). Apical 1 (1' ?, Figures 1 and 4) has become so constricted anteriorly that it has lost contact with the apex. Apical 1' is indented in the region of the girdle by the anterior plate of the ventral area.

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[1] In this report the term "red tide" is defined as discoloration of brackish or salt water caused by large numbers of organisms, with or without accompanying mortality of aquatic life.

The sulcus extends from the girdle to the antapex and is composed of the ventral area with small contributions from postcingulars 1''' and 6'''. Postcingular 1''' is very small and is rectangular.

In addition to the anterior attachment pore (A, Figures 1 and 4) there is another pore in the closing plate of the apex. This pore is lunate and is here called the ventral pore (V).

Chains are produced by repeated fission and protoplasmic continuity is accomplished by a slender strand of protoplasm passing through the the anterior and posterior attachment pores. These pores were observed in all specimens regardless of location in the chain.

The cytoplasm is reddish–brown and packed with granular bodies. Vacuoles that stain with Sudan IV are arranged peripherally. An iodine test for starch produced no blue color.

The nucleus (Figure 3), with moniliform chromatin threads, is large and lunate and the open end is always oriented ventrally.

The length and transdiameter were measured in 970 specimens. The mean length is 37.4 μ (range = 24.1–51.6 μ; standard deviation = 4.6 μ) and the mean transdiameter is 57.4 μ (range = 37.8–75.7 μ; standard deviation = 5.7 μ). The mean dorsoventral diameter, as determined by measurement of 157 single individuals (not in chains), is 49.7 μ (range = 34.4–61.9 μ; standard deviation = 4.8 μ) and the girdle width is approximately 5 μ.

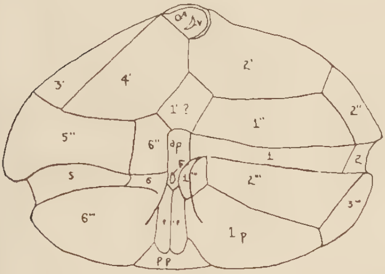
DISTRIBUTION. Taken in plankton from all stations in the Indian and Banana Rivers, Florida in August and September 1951 (salinity range = 18 to 32 0/00; temperature range = 30° to 34° C.) and in one sample at City Pier, Sarasota, Florida, on September 14, 1951.

COMPARISONS. Although *Gonyaulax monilata* and *G. catenella* Whedon and Kofoid (1936) seem to be closely related, the patterns of thecal sutures manifest significant differences. These differences are so great, in fact, as to cast some doubt on the inclusion of the present species in the genus *Gonyaulax* as described by Diesing and emended by Kofoid (1911a). This description of the genus allows no variation in the number of precingular plates.

The most significant difference between *Gonyaulax monilata* and *G. catenella* is in what is here called the first apical plate (1' ?, Figures 1 and 4). If this is an apical plate the anterior constriction evident in many species of *Gonyaulax* (*e.g. G. polyedra*, *G. polygramma*, *G. scrippsae*) has been carried to the ultimate extreme and the plate is so constricted as to have lost contact with the apex. Such extreme constriction could conceivably result from rapid multiplication associated with chain formation.

The alternative interpretation of this plate is as a precingular. This would make the number of apicals three and the number of precingulars seven. By traditional taxonomical procedure the present species would then be excluded from the genus *Gonyaulax* and would take a place as the type species of a poorly defined genus. This alternative is not attractive to the author and does not seem justified at this juncture.

On the basis of the plate pattern of the hypotheca (which does not vary in *Gonyaulax*) and the interpretation of plate 1' ? as an apical by virtue of its relation to precingulars 1'' and 6'' and the anterior plate of the ventral area, the present species is assigned to the genus *Gonyaulax* pending a re-examination and redescription of this genus and the small genera closely related to it.



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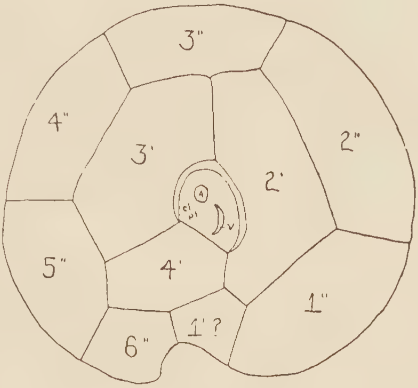

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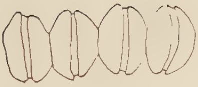

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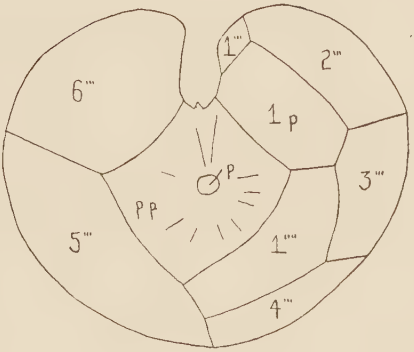

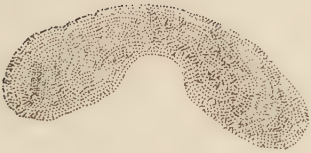

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5

FIG. 1. Ventral view of *Gonyaulax monilata* sp. nov. (× 735).
FIG. 2. Four individuals in catena (× 160).
FIG. 3. Apical view of nucleus (× 1000).
FIG. 4. Plate pattern of epitheca (× 1000).
FIG. 5. Plate pattern of hypotheca (× 1000).

ABBREVIATIONS: 1'–4', apical plates; 1''–6'', precingular plates; 1–6, girdle plates; 1'''–6''', postcingular plates; 1'''', antapical plate; 1 p, posterior intercalary plate; ap, anterior plate of ventral area; ip, intermediate plates; pp, posterior plate; A, anterior attachment pore; P, posterior attachment pore; V, ventral pore; F, flagellar pore.

This assignment is further strengthened by the similarity, both morphological and physiological (synthesis of a toxin), to *Gonyaulax catenella*.

Gonyaulax monilata also bears a very general resemblance to two other catenulate forms, *G. catenata* (Levander) Kofoid and *G. series* Kofoid and Rigden. It differs from the former in the number and arrangement of apical plates (Kofoid 1911b) and from the latter in the form of protoplasmic continuity (Kofoid and Rigden 1911).

Connell and Cross (1950) described a red tide in Offatts Bayou, Galveston, Texas, and attributed it to a dinoflagellate they believed to be *Gonyaulax catenella*. Since specific identification was not made and the plate pattern was not reported, accurate comparison with *G. monilata* is not possible.[2]

REMARKS. The difficulty in determining the generic relationship of this organism stresses the need for a revision of the genus *Gonyaulax* and related genera.

LITERATURE CITED

CONNELL, C. H., AND J. B. CROSS. 1950. Mass mortality of fish associated with the protozoan *Gonyaulax* in the Gulf of Mexico. Science, 112: 359–363.

KOFOID, C. A. 1911a. Dinoflagellata of the San Diego region. IV. The genus *Gonyaulax*, with notes on its skeletal morphology and a discussion of its generic and specific characters. Univ. Calif. Publ. Zool., 8: 187–286.

1911b. On the skeletal morphology of *Gonyaulax catenata* (Levander). Univ. Calif. Publ. Zool., 8: 287–294.

KOFOID, C. A., AND E. J. RIGDEN. 1911. A peculiar form of schizogony in *Gonyaulax*. Bull. Mus. Comp. Zool., Harvard, 54: 335–349.

WHEDON, W. F., AND C. A. KOFOID. 1936. Dinoflagellata of the San Francisco region. I. On the skeletal morphology of two new species, *Gonyaulax catenella* and *Gonyaulax acatenella*. Univ. Calif. Publ. Zool., 41: 25–34.

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[2] On September 5, 1952, the author examined a sample from Offatts Bayou containing a chain-forming dinoflagellate. The plates were identical to those of *Gonyaulax monilata* and measurement of 50 specimens gave the following mean dimensions: Transdiameter—50.3 μ; Length—33.6 μ. The mean dorsoventral diameter of ten specimens was 48.3 μ.

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SOUTHEASTERN ALASKA EXPLORATORY HERRING FISHING OPERATIONS, WINTER 1952/53

By Lawrence N. Kolloen* and Keith A. Smith**

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SUMMARY

Explorations to determine the feasibility of winter herring fishing in Southeastern Alaska were conducted in the winter of 1952/53. Under a cooperative program between the U. S. Fish and Wildlife Service and the Alaska herring industry, the exploratory fishing vessel John N. Cobb explored the waters of Southeastern Alaska between November 4 and December 19, 1952. An amendment to the Alaska fishery regulations permitted the operation of four commercial herring seiners in the waters south of 55°N. latitude between November 9, 1952, and February 11, 1953.

With the exception of a few areas, herring were not found to be abundant during this period. The John N. Cobb did not find herring on the grounds customarily exploited by the summer fishery. Although indications of herring were obtained in Port Camden, Seymour Canal, George Inlet, Silver Bay, Tongass Narrows, and Kendrick Bay, only in the latter three localities were there indications of abundance. The catch of the commercial seiners was approximately 30,000 barrels, 68 percent of which came from Kendrick Bay. Catches were also made in McLean Arm, Foggy Bay, Nakat Bay, Boca de Quadra, and Yes Bay. The most significant concentration of herring was in Tongass Narrows, which was closed by regulation to fishing for reduction purposes.

Herring from Kendrick Bay (which provided the bulk of the catch) were small. Fairly large herring were obtained from the localities of Foggy Bay, Nakat Bay, and Boca de Quadra. The Tongass Narrows herring were of mixed size, averaging much larger than those of Kendrick Bay, but not equal in size to those of Nakat Bay.

Herring in their second year of life were predominant in the catch from Kendrick Bay. The Foggy Bay, Nakat Bay, and Boca de Quadra catches showed a greater spread of ages with a predominance of 3-year and 6-year fish. The Tongass Narrows fish were of mixed age, ranging from 1 to 6 years.

Laboratory analysis showed the winter herring to be approximately 13½ percent oil by weight. The oil yield of slightly less than 3 gallons per barrel of raw fish processed,

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which was obtained in the commercial operations, was less than the 5 gallons normally obtained in the summer operations. No increase in oil content was noted with increased age, as has been the experience in the summer catch.

During November and December, unusually mild weather prevailed in Southeastern Alaska. Interruptions to fishing by weather in the commercial operations amounted to 30 days, or roughly one-third of the operating period.

It was observed that in winter the herring tend to stay at much greater depths than in the summer period, which suggests that the use of deeper nets, such as employed in the Canadian fishery, may be nessary for successful winter fishing.

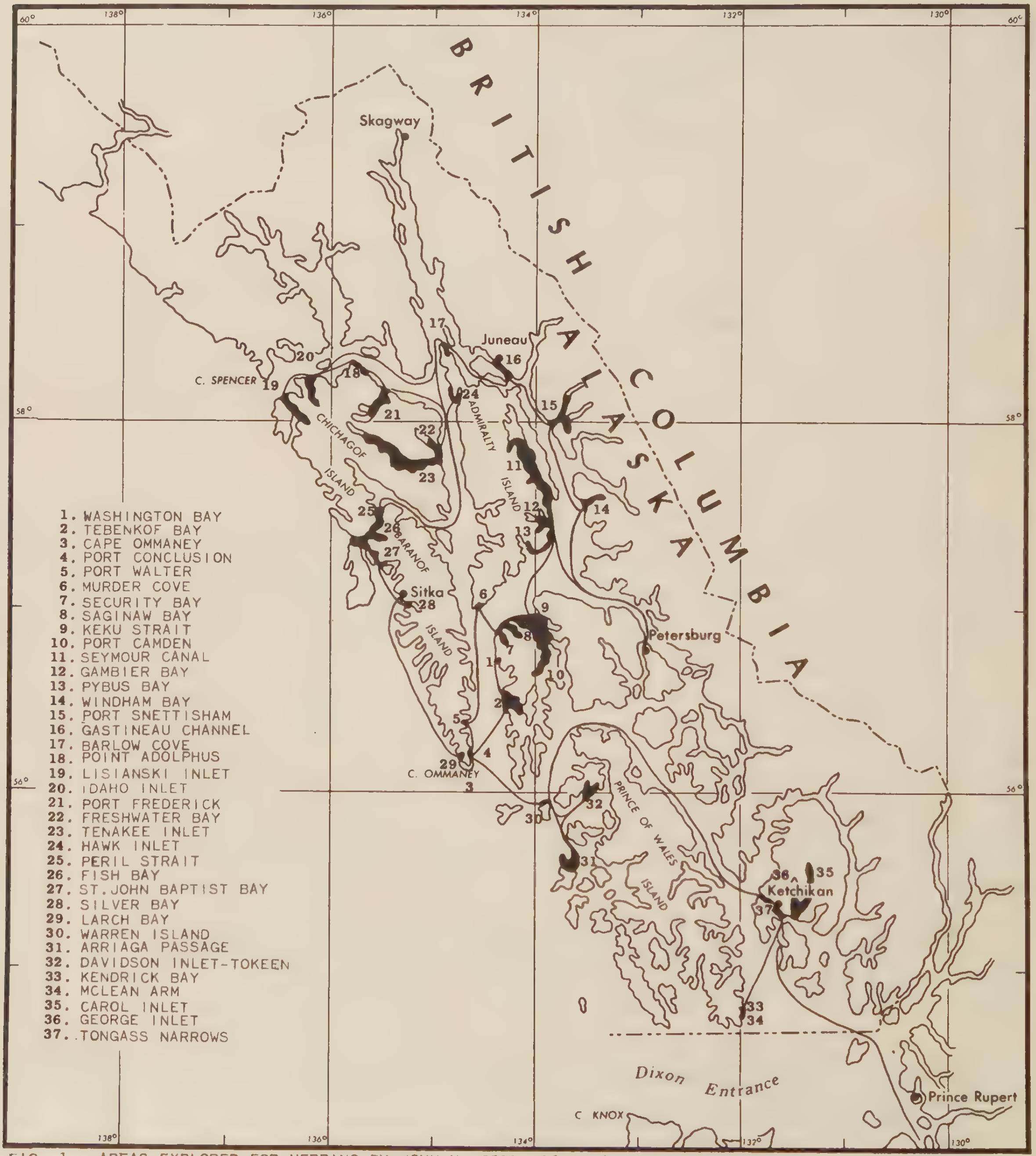
60°
138°
136°
134°
132°
130°
58°
56°
BRITISH COLUMBIA
ALASKA
Skagway
Juneau
C. SPENCER
CHICHAGOF ISLAND
ADMIRALTY ISLAND
BARANOF ISLAND
Sitka
Petersburg
C. OMMANEY
PRINCE OF WALES ISLAND
Ketchikan
Dixon Entrance
C KNOX
Prince Rupert
1. WASHINGTON BAY
2. TEBENKOF BAY
3. CAPE OMMANEY
4. PORT CONCLUSION
5. PORT WALTER
6. MURDER COVE
7. SECURITY BAY
8. SAGINAW BAY
9. KEKU STRAIT
10. PORT CAMDEN
11. SEYMOUR CANAL
12. GAMBIER BAY
13. PYBUS BAY
14. WINDHAM BAY
15. PORT SNETTISHAM
16. GASTINEAU CHANNEL
17. BARLOW COVE
18. POINT ADOLPHUS
19. LISIANSKI INLET
20. IDAHO INLET
21. PORT FREDERICK
22. FRESHWATER BAY
23. TENAKEE INLET
24. HAWK INLET
25. PERIL STRAIT
26. FISH BAY
27. ST. JOHN BAPTIST BAY
28. SILVER BAY
29. LARCH BAY
30. WARREN ISLAND
31. ARRIAGA PASSAGE
32. DAVIDSON INLET-TOKEEN
33. KENDRICK BAY
34. MCLEAN ARM
35. CAROL INLET
36. GEORGE INLET
37. TONGASS NARROWS

FIG. 1 - AREAS EXPLORED FOR HERRING BY JOHN N. COBB, SOUTHEASTERN ALASKA, WINTER 1952. LINES SHOW COURSES RUN WITH ECHO SOUNDER IN OPERATION.

A total of 5,397 herring were tagged with internal belly tags to determine if there is a southward migration of Southeastern Alaska herring into British Columbia. Eight recoveries have been made to date, but these recoveries have all come from the same locality in which the fish were tagged, and furnish no information on migration. The British Columbia fishery did not operate in the season of 1952/53, so that chances for recovery in that area have been lost for this season.

These explorations did not result in finding numerous concentrations of herring, but do not eliminate the possibility of developing a winter herring fishery in this area. Where herring were found, they were abundant, as shown by the high average catch per set of the commercial boats. Had the herring in Tongass Narrows been available to the fishery, the commercial operations would have been more successful. Tongass Narrows appears to be comparable to Ogden Channel in northern British Columbia as an assembly area of the prespawning schools. The Ogden Channel area contributed 480,000 barrels to the British Columbia herring catch in 1951/52. Whether the herring industry will venture further winter operations in Southeastern Alaska will depend on the market for fishery byproducts.

BACKGROUND INFORMATION

A matter of great interest to those concerned with the Alaska herring fishery has been the sustained high production in British Columbia contrasted to the recent low production in Southeastern Alaska. For the five-year period from 1948 through 1952, the catch in British Columbia has been approximately 11 times that of Southeastern Alaska.

British Columbia and Southeastern Alaska Herring Catches, 1947/48-1951/52 Seasons

British Columbia		Southeastern Alaska	
Season	Catch	Season	Catch
	Short Tons		Short Tons
1951/52	198,000	1952	17,600
1950/51	187,300	1951	14,100
1949/50	183,200	1950	15,700
1948/49	190,100	1949	17,700
1947/48	171,700	1948	18,700

Although fishing effort in British Columbia has exceeded that in Southeastern Alaska, this alone does not satisfactorily explain the marked difference in production. The poor catches in Southeastern have been caused primarily by a scarcity of herring resulting either from reduced abundance or reduced availability. Under these circumstances it is doubtful that any increase in fishing effort would have resulted in a marked improvement of the catch.

Because these areas are in adjacent geographical positions and presumably have similar conditions of environment, it would be natural to expect comparable productive capacity and at least similar patterns of abundance.

It has been suggested that the difference in production may be due to the difference in fishing season. British Columbia herring are fished from November to the middle of March; those of Alaska from June through September. British Columbia investigators believe that their major herring populations are offshore in summer and do not become available inshore until the prespawning runs of late fall and winter. This has been confirmed, at least insofar as one population is concerned, by exploratory catches made on Swiftsure Bank in July 1953. Tag recoveries revealed that these fish had been tagged during the spring spawning period in the inshore waters of Barkley Sound. Obviously, a summer fishery confined only to shore areas would have missed these fish entirely.

Similarly, an offshore movement by Alaska herring might cause these populations to escape the summer fishery which is conducted relatively close to shore. In this event the fluctuations in the summer catches might be influenced more by annual or cyclic variation in the offshore movements than by actual changes in abundance.

It has also been suggested that the declining yields in Southeastern Alaska coincident with increasing yields in British Columbia have been caused by changes in migratory pattern. Alaska fishermen have expressed the opinion that the Southeastern Alaska herring are now bypassing that area in favor of British Columbia waters. This theory presumes a southward migration of the Southeastern Alaska herring stocks.

In British Columbia in recent years the high production in the northern subdistrict has contributed materially to the success of the herring fishery. Following good yields (chiefly from the Prince Rupert area) in the period of 1937-1942, production in this sub-

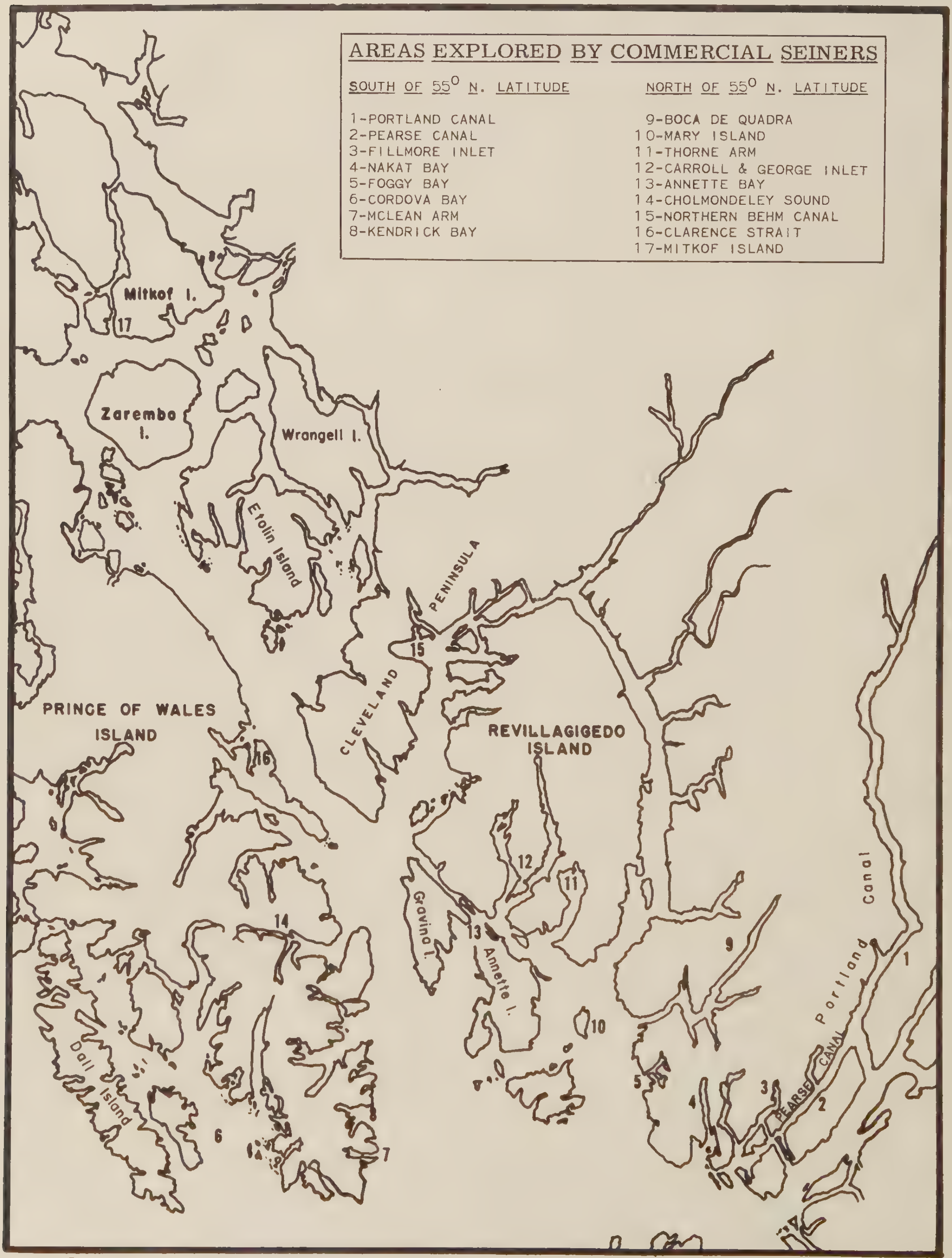
AREAS EXPLORED BY COMMERCIAL SEINERS
SOUTH OF 55° N. LATITUDE
1-PORTLAND CANAL
2-PEARSE CANAL
3-FILLMORE INLET
4-NAKAT BAY
5-FOGGY BAY
6-CORDOVA BAY
7-MCLEAN ARM
8-KENDRICK BAY
NORTH OF 55° N. LATITUDE
9-BOCA DE QUADRA
10-MARY ISLAND
11-THORNE ARM
12-CARROLL & GEORGE INLET
13-ANNETTE BAY
14-CHOLMONDELEY SOUND
15-NORTHERN BEHM CANAL
16-CLARENCE STRAIT
17-MITKOF ISLAND
Mitkof I.
17
Zarembo I.
Wrangell I.
Etolin Island
PENINSULA
15
CLEVELAND
PRINCE OF WALES ISLAND
16
REVILLAGIGEDO ISLAND
12
11
Gravina I.
13
Annette I.
14
9
Canal
Portland
1
10
5
4
3
PEARSE CANAL
2
Dall Island
6
7

FIG. 2 - AREAS EXPLORED BY COMMERCIAL HERRING SEINERS, SOUTHEASTERN ALASKA, WINTER 1952/53.

district declined sharply in the period 1943-1948. With the discovery in the 1948/49 season of a large concentration of herring in Ogden Channel, the catch in this subdistrict has increased each year to a high of 57,300 tons in the 1951/52 season. The apparent abundance of herring in this subdistrict, which bounds on the international border, has aroused considerable speculation as to whether these stocks might not also be available to Alaskan fishermen in the Dixon Entrance area.

To determine if herring are sufficiently abundant in Southeastern Alaska during November and December to support reduction operations, the Service organized an exploratory fishing expedition in the fall of 1952. In planning these activities, it was proposed to tag herring to the extent that it would not seriously interfere with the exploratory work. The purpose was to determine if there is a southward movement of Alaska herring into British Columbia waters. It was decided to tag on the United States side of Dixon Entrance to see if any recoveries would be obtained from the British Columbia fishery during the ensuing winter period.

The exploratory expedition was sponsored jointly by the U. S. Fish and Wildlife Service and the Alaska herring industry. The Exploratory Fishing and Gear Development Section of the Service's Branch of Commercial Fisheries furnished the exploratory fishing vessel John N. Cobb. The Branch of Fishery Biology furnished biologists for tagging and the collection of biological data. The Alaska herring reduction operators furnished a purse seine and other items of fishing gear. The Alaska Department of Fisheries placed a biologist on board the John N. Cobb as an observer and to assist in tagging operations.

In the same period in which this expedition was being organized, a request was received from the industry to allow herring fishing for reduction purposes in the Dixon Entrance area. Favorable action on this request by the Service resulted in commercial fishing in waters south of 55° N. latitude during the winter of 1952/53.

The following report deals both with the explorations by the Service vessel John N. Cobb and fishing by commercial vessels since both operations furnish information on the availability of herring during the winter months.

SCOPE OF EXPLORATIONS OF THE JOHN N. COBB

The John N. Cobb operated between November 4 and December 19, 1952. The area explored extended from Dixon Entrance to Icy Strait, including Tongass Narrows, lower Clarence Strait, Sea Otter Sound, Chatham Strait, Frederick Sound, Seymour Canal, Stephens Passage, Peril Strait, and the south side of Icy Strait. (The daily log of the John N. Cobb is Appendix B.)

The gear employed was a standard Alaska herring purse seine 200 fathoms long. This seine was six strips deep, each strip consisting of 200 meshes of $1\frac{1}{2}$-inch stretched measure between knots. The maximum fishable depth of this seine was approximately 10 fathoms. In addition to the purse seine, a lampara bait seine was carried. (Details of modifications of the John N. Cobb required for purse-seine operation, net construction, and operation are contained in Appendix A.)

The echo sounder used in sounding for herring was a Bendix model DR-6. This instrument gives a choice of two depth ranges: 0 to 400 feet and 0 to 400 fathoms, and makes an instantaneous and permanent graphical record of bottom depth and also of objects between the ship and the bottom. When running over fish, the depth and extent of the school are indicated by the tracing on the recording tape. Instruments of this type are now universally used by herring seiners in Alaska, and are considered essential for locating herring schools.

An experienced herring seiner captain was employed to assist in locating herring schools and to supervise actual seining operations.

SCOPE OF EXPLORATIONS BY COMMERCIAL VESSELS

On October 10, 1952, the Service amended Section 116.3 of the 1952 Alaska Fishery Regulations by extending the established closure date of October 15 to February 28 of the following year. The new closure date applied only to the waters south of 55° N. latitude. Herring fishing in Tongass Narrows for reduction purposes was prohibited. The provision which allowed for a take of 2,000 bbls.[1] per calendar month in the remainder of Southeastern Alaska was retained.

Two companies participated in the winter fishery: the Salmon By-Products Company located at Ketchikan, and the Oceanic Fisheries Company which operated the floating reduction barge Pacific Rim at Metlakahtla. Each company employed two large seiners with experienced herring fishermen and equipped with standard herring gear.

The Salmon By-Products Company was first in the field and began searching for herring with the seiners Storm and Fram on November 9. The Oceanic Fisheries Company did not begin actual fishing until December 10 with the seiners Oceanic and Vitanic. All fishing was terminated by February 11, 1953.

In the course of these operations, the vessels thoroughly scouted the waters south of 55° N. latitude and prospected to a lesser extent in areas north of that line. Inspection of logbooks kept by these vessels show that their explorations included the places indicated in figure 2.

RESULTS

OCCURRENCE OF HERRING: Except for a few localities, the findings of the John N. Cobb and the commercial vessels were largely negative. The localities in which herring were found by the John N. Cobb were Port Camden, Seymour Canal, Lisianski Inlet, Silver Bay, Kendrick Bay, George Inlet, and Tongass Narrows. Localities in which the commercial vessels succeeded in making catches were McLean Arm, Kendrick Bay, Foggy Bay, Nakat Bay, Boca de Quadra, and Northern Behm Canal (Yes Bay). Only in Silver Bay, Kendrick Bay, and Tongass Narrows were there indications of any real abundance.

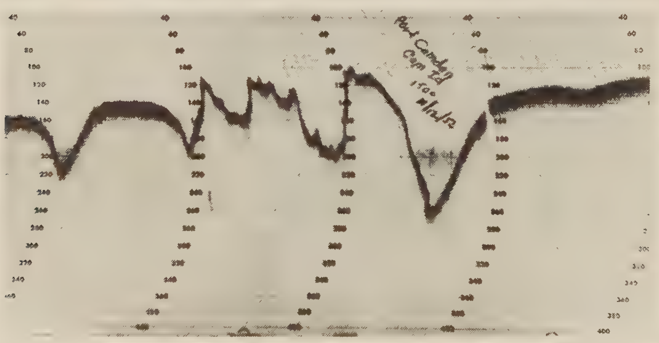

FIG. 3 - ECHO-SOUNDER TRACING OF HERRING SCHOOLS LYING IN BOTTOM DEPRESSIONS IN PORT CAMDEN, SOUTHEASTERN ALASKA, NOVEMBER 1952.

An investigation was made by the John N. Cobb of the principal fishing grounds commonly exploited during the summer fishery, namely Chatham Strait, Cape Ommaney, Larch Bay, Tobenkof Bay, Tyee, Point Adolphus, Warren Channel, and Noyes Island. For the most part these areas appeared to be devoid of herring, as indicated by the lack of birds and by the lack of depth-sounder tracings.

Port Camden was sounded by the John N. Cobb on November 12 and 13 (see figure 3). Several schools of herring which were lying in bottom depressions were too deep for capture by purse seine. At midnight a floodlight which was played on the water attracted some of these fish to the surface and two were caught by dip net.

Seymour Canal, sounded on November 13 and 14, contained two schools near the mouth of Pleasant Bay at depths of 20 to 80 feet.

Echo-sounder tracings were recorded in Lisianski Inlet on November 20 and 21. These schools, situated between Pelican City and Soloma Point, were not in suitable position for making a purse-seine set. Several moving brown spots were also observed in the water and remained near the beach in a manner characteristic of small fish. Some of these fish caught by means of the "herring jig" proved to be juvenile rockfish (Sebastodes emphaeus).

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[1] THE STANDARD HERRING BARREL CONTAINS 31.5 GALLONS AND HOLDS APPROXIMATELY 250 POUNDS OF FISH. EIGHT BARRELS ARE CONSIDERED EQUIVALENT TO ONE TON.

Soundings in George Inlet on December 11 showed a small school of herring at a depth of approximately 200 feet near the site of the Libby Cannery dock.

A large concentration of herring was discovered at the entrance to Silver Bay by **the John N. Cobb on December 1. The magnitude** of this body of fish is demonstrated by the echo-sounder tracings obtained (figure 4). At midday these schools were at depths of 220 to 260 feet. At dusk, and with the appearance of a full moon, some of these fish rushed to the surface. The subsequent flipping which appeared to extend over at least a square mile of area sounded like the fall of large hailstones on the water.

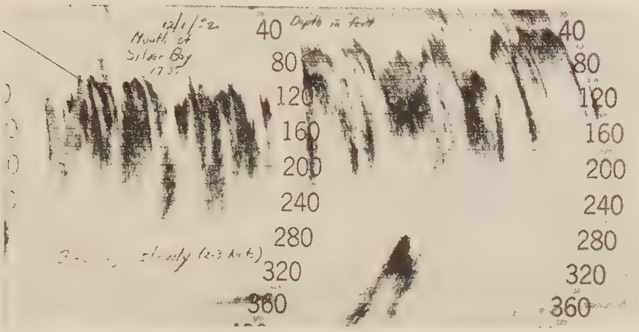

FIG. 4 - ECHO-SOUNDER TRACING OF HERRING SCHOOLS IN SILVER BAY, SOUTHEASTERN ALASKA, DECEMBER 1952.

The fishing captain judged these to be large fish by the sound of the flips. The set was unsuccessful because the fish sounded before the seine could be pursed, and the few small fish caught were obviously not representative of the main body of the school. It was anticipated that herring would be present in this area since it is the major herring spawning ground in Southeastern Alaska.

The most impressive showing of herring was in Tongass Narrows which contained an enormous body of herring throughout the winter months. It was reported by residents that the herring had first appeared in the Narrows in the latter part of October. On the John N. Cobb's first visit to this area on November 7, significant soundings were obtained at depths of 40 to 80 feet. On December 6 the John N. Cobb again sounded these waters and obtained the tracings shown in figure 5. On this date thousands of gulls and numerous sea lions were observed to be "working" on the herring schools. For about one hour following dusk the herring could be heard flipping at the surface over a wide area near the docks of Ketchikan.

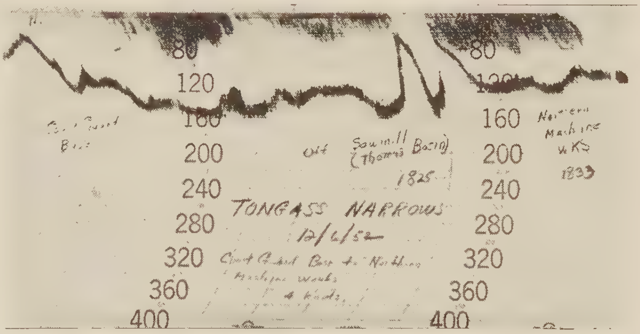

FIG. 5 - ECHO-SOUNDER TRACING OF HERRING SCHOOLS NEAR THE SURFACE IN TONGASS NARROWS, SOUTHEASTERN ALASKA, DECEMBER 1952.

The presence of large quantities of herring in Tongass Narrows is also substantiated by the echo soundings of the commercial vessels. Although these waters were closed to fishing for reduction purposes, the vessels frequently sounded them en route to and from the reduction plant. The tracings obtained were, in many instances, larger than those obtained by the John N. Cobb. All demonstrated a large mass of herring with both depth and width. The herring were mainly in the southern portion of the Narrows, extending from Potter Rock to the Ketchikan docks, a distance of approximately three miles. This concentration of herring was greater than any which the fishermen had previously observed during their experience in the summer fishery.

Approximately 15,000 barrels of herring were removed from Tongass Narrows during the winter of 1952/53 by the bait fishery.

The occurrence of herring in Kendrick Bay and McLean Arm on the southeast shore of Prince of Wales Island was established by the catch of approximately 20,000 barrels by the commercial vessels. The fact that they commonly loaded their holds in a single set is evidence that the herring were densely schooled. A set made by the John N. Cobb in Kendrick Bay on the night of December 8 yielded a catch of approximately 1,500 barrels.

Table 1--Catch by Reduction Fishery, Southeastern Alaska, Winter 1952/1953

Date	Locality						Total
	McLean Arm	Kendrick Bay	Foggy Bay	Nakat Bay	Boca de Quadra	Northern Behm Canal	
	(In 250-pound barrels)						
Nov. 1952:							
15	500						500
28		886					886
29		1,039					1,039
Dec. 1952:							
2		1,157					1,157
5		1,026					1,026
8		1,126					1,126
10		1,034					1,034
14		798					798
15		871					871
16		1,067					1,067
17	973						973
18		2,044					2,044
19		314					314
22	510						510
23		193					193
26		1,111					1,111
27		779					779
30		1,373					1,373
31		901					901
Jan. 1953:							
3		373					373
5		1,529					1,529
6		931					931
17			1,115				1,115
20			1,109				1,109
21				1,443			1,443
22				1,061			1,061
23				2,013			2,013
24				1,089			1,089
28					1,081		1,081
Feb. 1953:							
5						831	831
Total	1,983	18,552	2,224	5,606	1,081	831	30,277

The commercial vessels also reported a fair showing of fish in Boca de Quadra. Because this locality lies north of 55° N. latitude, their catch was necessarily limited by the regulation which restricted the combined catch in waters north of this line to 2,000 barrels per calendar month.

Catches from other areas which contributed to the 30,000-barrel take of the commercial fishery are shown in table 1.

LENGTH AND WEIGHT OF HERRING: Two length measurements were taken from each fish. Body length, customarily used in measuring herring, is the distance from the tip of the snout to the end of the silvery area on the caudle peduncle after the scales have been removed from this area. Total length is the distance from the tip of the snout to the tip of the tail. Average lengths and weights are shown in table 2.

The data from Kendrick Bay in table 2 is of special interest since this locality provided the major part of the commercial catch. These fish, which averaged only 5.8 inches in body length and 1.3 ounces in weight, were small in contrast to those caught in all of Southeastern Alaska in the summer of 1952. The summer fish averaged 8.1 inches in body length and 4.3 ounces in weight.

Catches in Foggy Bay, Nakat Bay, and Boca de Quadra were a mixture of sizes averaging much larger than the uniformly small Kendrick Bay herring. The large Nakat Bay fish, with an average body length of 8.0 inches and an average weight of 4.2 ounces, compare favorably in size to those taken in the summer fishery.

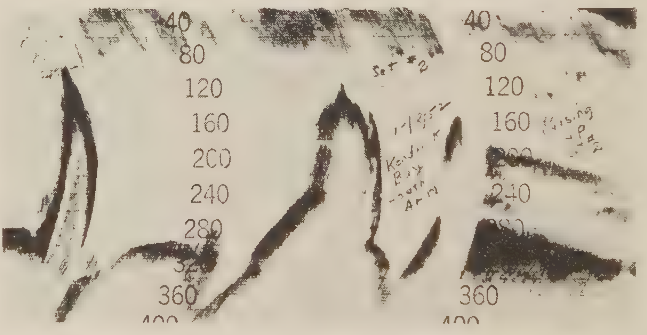

FIG. 6 - ECHO-SOUNDER TRACING OF HERRING SCHOOLS IN KENDRICK BAY, SOUTHEASTERN ALASKA, DECEMBER 1952.

Two samples of herring were obtained from Tongass Narrows. These samples show the Tongass Narrows fish to be of mixed sizes, considerably larger than the Kendrick Bay fish, but not equal to those of Nakat Bay. Body length averaged 7.2 inches and body weight averaged 3.0 ounces.

AGE OF HERRING: The age of the herring in all samples was obtained by examination of the scales on which an annulus or winter check is formed each year. A fish with two annuli on its scale is two years old and is so designated by Roman numeral "II." Such a fish is in its third year of life and so designated by Arabic figure "3." Year class signifies the year in which the fish was spawned. Thus, for example, a fish taken in December 1952 with two annuli on its scale would be II years old, in its 3rd year of life, and of the year class of 1950.

The marked difference in age composition of catches from McLean Arm and Kendrick Bay in lower Clarence Strait from those of Foggy Bay, Boca de Quadra, and Nakat Bay in lower Revillagigedo Channel, is apparent in figures 7 and 8. These localities are roughly 35 miles apart. The McLean Arm and Kendrick Bay samples are comprised almost exclusively of 2-year fish from the year class of 1951. The Foggy Bay, Boca de Quadra, and Nakat Bay samples show a much greater spread in ages with a fair proportion of older fish. Most strongly represented in the latter samples are the 3-year fish of the year class of 1950 and the 6-year fish of the year class of 1947. The age composition of the Tongass Narrows herring is similar to that found in the lower Revillagigedo Channel district.

Table 2 - Average Lengths and Weights of Herring, Southeastern Alaska, Winter 1952/53.

Locality of Catch	Date	Boat	Fish in Sample	Avg. Body Length	Avg. Total Length	Avg. Weight
			Number	Inches	Inches	Ounces
Port Camden	11/12/52	Cobb[1]	2	4.65	5.49	0.74
Silver Bay	12/1/52	Cobb[2]	66	4.32	5.11	0.65
McLean Arm	12/22/52	Storm	50	5.76	6.81	1.32
Kendrick Bay	12/8/52	Fram	100	5.77	6.81	1.30
	12/9/52	Cobb	51	5.98	7.03	1.41
	12/14/52	Fram	50	5.87	6.88	1.37
	12/18/52	Fram	50	5.77	6.80	1.32
	12/23/52	Fram	50	5.71	6.76	1.29
	12/26/52	Vitanic	50	6.00	7.06	1.39
	12/30/52	Vitanic	54	5.76	6.87	1.32
	1/6/53	Oceanic	33	5.46	6.91	1.42
	Weighted average			5.80	6.90	1.34
Foggy Bay	1/17/53	Fram	50	7.24	8.47	2.82
	1/20/53	Storm	50	6.91	8.18	2.52
	Weighted average			7.08	8.33	2.67
Boca de Quadra	1/28/53	Storm	100	6.68	7.86	2.39
Nakat Bay	1/21/53	Oceanic	23	8.16	9.64	4.32
	1/21/53	Vitanic	15	7.35	8.71	3.20
	1/22/53	Oceanic	38	8.20	9.62	4.43
	Weighted average			8.02	9.44	4.15
Tongass Narrows	12/11/52	Pirate	126	7.26	8.52	3.09
	Dec.	Cold St.	100	7.17	8.44	2.91
	Weighted average			7.22	8.48	3.00
Tongass Narrows	12/15/52	Cobb[3]	50	5.37	6.37	0.90

[1] CAPTURED BY DIP NET FROM FISH BROUGHT TO SURFACE BY FLOODLIGHT.

[2] SAMPLE NOT REPRESENTATIVE BECAUSE SCHOOL SOUNDED AND THE ONLY FISH TAKEN WERE SMALL ONES WHICH HAD GILLED IN THE WEB.

[3] CAPTURED WITH SHALLOW LAMPARA SEINE.

OIL CONTENT: The herring in each sample were segregated into age groups and each age group was ground separately. From the resulting mass a small sample was removed, and this was used for determination of the oil content of the particular age group concerned. The remaining portions of all age groups were then thoroughly mixed together. A small sample removed from this mass was used to determine the oil content of the sample as a whole. In samples consisting almost entirely of a single age, analysis was limited to this age only, under the assumption that it would adequately represent the sample as a whole. The oil content was determined by acid hydrolysis and extraction with ethyl ether and petroleum ether. The results of these determinations as expressed in percent of total weight are shown in table 4.

The recovery of 13.51 percent by weight from all samples analyzed is considerably greater than the recovery of approximately 9 percent achieved in the commercial operations. This is accounted for by the fact that separation by chemical means is more efficient than by the settling tank and centrifuge process used by the reduction plants. In the winter fishery, the oil yield was slightly under 3 gallons per 250-pound barrel of raw fish processed as compared to an oil yield of 5 gallons per barrel normally obtained in the summer fishery.

A decrease in oil yield between the summer and winter fish was not unexpected since the fat accumulated during the summer feeding period is utilized in the development of sexual products during the late fall and winter. Hart, Tester, Beall, and Tully (1940) in their study of changes in the condition factor of British Columbia herring report that "a maximum oil content is reached in July and is fairly well sustained throughout the summer. In October the oil content starts to fall quite rapidly, reaching a very low value about spawning time in March." This pattern of seasonal oil change is also applicable to Southeastern Alaska herring.

Table 3--Age Composition of Herring Catches, Southeastern Alaska, Winter 1952/53

Locality of Catch	Year Class	1952	1951	1950	1949	1948	1947	1946	1945	1944	Total
	Year of Life	1	2	3	4	5	6	7	8	9	
McLean Arm	Number		49	1							50
	Percent		98.0	2.0							100
Kendrick Bay	Number		429	11	1	2	1				444
	Percent		96.6	2.5	0.2	0.5	0.2				100
Foggy Bay	Number		14	64	9	3	9	1			100
	Percent		14.0	64.0	9.0	3.0	9.0	1.0			100
Boca de Quadra	Number	1	18	55	12	5	9				100
	Percent	1.0	18.0	55.0	12.0	5.0	9.0				100
Nakat Bay	Number	1	2	22	6	14	27	2		2	76
	Percent	1.3	2.7	29.0	7.9	18.4	35.5	2.6		2.6	100
Tongass Narrows	Number	3	49	74	33	47	20				226
	Percent	1.3	21.7	32.7	14.6	20.8	8.9				100

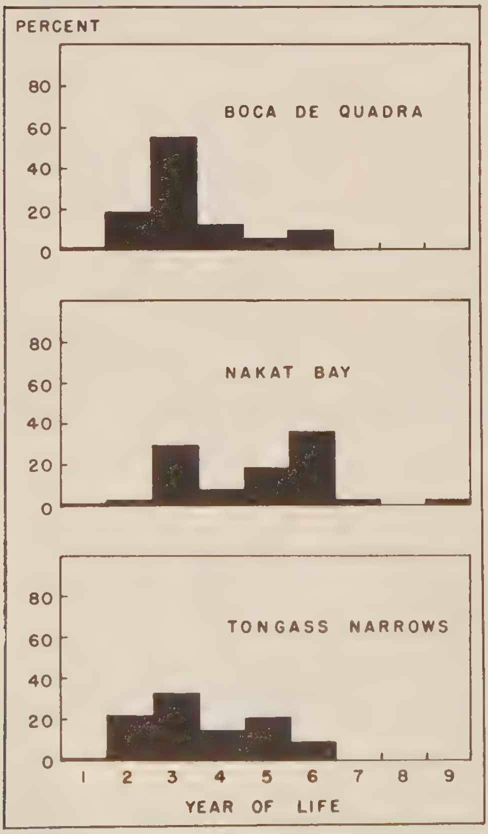

FIG. 7 - PERCENTAGE AGE COMPOSITION OF HERRING CATCHES, SOUTHEASTERN ALASKA, WINTER 1952/53.

Except for fish in their first year of life, these data show little difference in oil content with respect to age. This is somewhat surprising in view of studies[2] made in 1942 of summer catches in the Kodiak Island district, which showed fish in their second year to be 7.7 percent, fish in their third year 16.4 percent, and fish in their fourth year 21.8 percent oil by weight. There appeared to be no significant increase in oil content beyond the fourth year. From this background a similar pattern was anticipated for the winter catches in Southeastern Alaska.

Failure to obtain such a pattern may be entirely due to the small number of samples in these determinations, or it may be possible that because the "belly fat" has been converted into milt or roe by midwinter, differences in oil content between herring of different ages is relatively slight. The high percentage of oil in the 2-year fish from Kendrick Bay might be explained by the fact that these were nearly all in their second year and sexually immature. In this group, individuals with developing gonads were extremely rare, indicating that the majority would not spawn in the following spring. Most, however, contained ester or "belly fat" in the body cavity, which was not usually present in fish which had developed spawning products.

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[2] UNPUBLISHED DATA OF THE U. S. FISH AND WILDLIFE SERVICE.

WEATHER AND EFFECT ON OPERATIONS: During the period of survey by the *John N. Cobb* (November 9 to December 16), unusually mild weather prevailed over Southeastern Alaska. Daily air temperatures recorded by the *John N. Cobb* ranged from 30° F. to 49° F., with an average of 40.5° F. Surface water temperatures ranged from 39° F. to 47° F., with the coldest waters at the heads of bays and inlets, and the warmest waters in the open coastal areas. Average surface temperature was 42.5° F. No ice was encountered at the heads of bays as would normally be expected at this time of year.

Table 4--Oil Content (Expressed as Percent of Total Weight) of Herring Taken in Southeastern Alaska, Winter 1952/53

Date	Locality	Boat	Year of Life							
			1	2	3	4	5	6	7	Composite
12/1/52	Silver Bay	Cobb	7.65	11.01	13.01					11.22
12/22/52	McLean Arm	Storm		13.65						-
12/9/52	Kendrick Bay	Cobb		13.77						-
12/18/52		Fram		13.37						13.30
12/23/52		Fram		12.41						-
12/26/52		Vitanic		13.05						-
1/17/53	Foggy Bay	Fram		10.63	12.80	13.23		11.59		14.65
1/20/53		Storm			14.59					13.03
1/28/53	Boca de Quadra	"		10.73	12.21	12.21	13.12	13.24		12.45
12/11/52	Tongass Narrows	Pirate			14.28	15.34	14.93	15.28	16.00	14.41
12/15/52		Cobb	5.11	10.42						-
Dec. ?		?			14.67	14.16	13.92	14.00		14.08
Weighted average, all samples			7.24	12.41	13.50	13.94	14.06	13.87	16.00	13.51

Four storms of gale force were experienced. The prevailing winds were southeasterly to southwesterly, moving warm air inward from the ocean areas. The outside waters were generally too rough for seining, which was also true of the exposed waters of Chatham Strait. It was concluded that any seining operations in that area would be subject to much loss of fishing time because of weather.

The commercial operations conducted between November 9 and February 11 included 94 days of fishing time. On 21 of these days the boats could not fish because of storms. This does not include the loss of an additional 9 days caused by a severe cold spell between January 5 and January 14 which caused the nets to freeze. Total interference to fishing operations amounted to 30 days, or approximately one-third of the total time. The cold spell caused ice to form in some of the smaller bays, including Kendrick Bay which had been the principal fishing ground up to that time.

HERRING BEHAVIOR, WINTER AND SUMMER: A noteworthy observation obtained from these experiments is the difference in behavior between the herring schools in the winter and summer seasons. In winter the herring appear to stay close to the bottom and generally at much greater depths. In this period the schools appar-

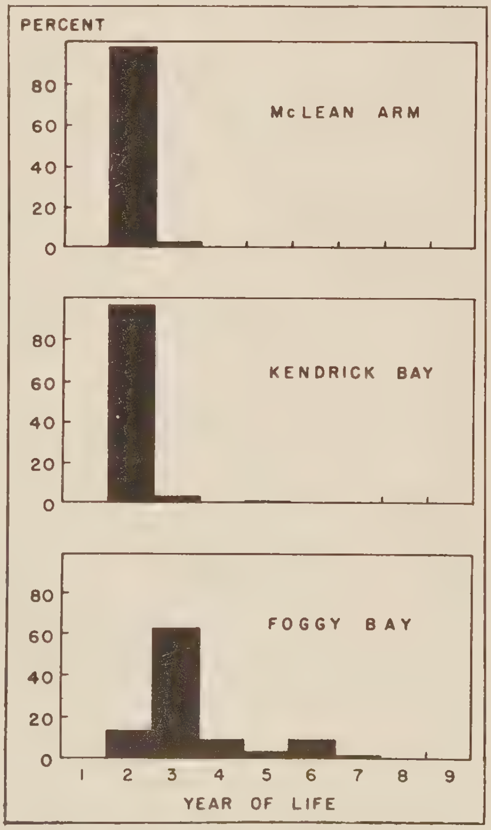

FIG. 8 - PERCENTAGE AGE COMPOSITION OF HERRING CATCHES, SOUTHEASTERN ALASKA, WINTER 1952/53.

ently congregate at certain localities where they remain until the approach of spawning in the spring. During the summer months the herring schools are constantly moving in search of food and do not appear in such dense concentrations as in the winter period.

These differences suggest that some modifications of fishing technique may be necessary for the development of successful winter operations. In this regard it is considered significant that the nets used by the Canadians are much deeper than those which have been used in Alaska. The Alaska seines, which are six to eight strips deep, fish effectively from 60 to 90 feet. The Canadian seines, which are twelve to fourteen strips, fish effectively at depths of 120 to 150 feet.

Table 5--Herring Tags Affixed in Southeastern Alaska, 1952

Date	Locality	Series	Number
12/8/52	South Arm Kendrick Bay	USF 3-A	492
"	"	" 4-A	299
12/9/52	"	" 7-A	999
"	"	" 8-A	200
Total			1,990
12/15/52	Tongass Narrows	" 9-A	819
"	"	" 1-B	988
"	"	" 2-B	1,000
12/16/52	"	" 3-B	600
Total			3,407
Grand total			5,397

Finding herring in the winter is dependent almost entirely on the use of echo-sounding instruments. It is only rarely that the presence of herring can be detected by flips or feeding birds, as is frequently possible during the summer months.

TAGGING: A total of 5,397 herring were tagged, 1,990 in Kendrick Bay and 3,407 in Tongass Narrows (table 5). The international boundary line is approximately 15 miles south of Kendrick Bay and approximately 50 miles south of Tongass Narrows. In both localities the fish were caught by the *John N. Cobb*. A purse seine was used at Kendrick Bay and a lampara bait seine at Tongass Narrows. The catches in both localities consisted almost entirely of herring in their second year.

The tags used in this experiment were the internal metal belly tags customarily employed in tagging herring. These tags were 3/4-inch long, 5/32-inch wide, and 1/16-inch thick, rounded at both ends. Each tag bore the symbols USF, and an identifying serial number.

Although there is an appreciable tagging mortality, the internal metal tags have proven successful for tagging herring. The magnetic properties of these tags allow for their recovery by electro-magnets installed in the meal lines of the reduction plants. The plants in both southeastern Alaska and British Columbia are equipped with such magnets.

The tagging crew consisted of four men working in teams of two, one holding the fish in position and the other inserting the tag. With the fish held belly up, a small incision was made just above and anterior to the base of the ventral fin. The tag was then gently pushed through this opening into the coelomic cavity of the fish. All tagged fish were returned to the seine, from which all fish, both tagged and untagged, were later released as a school.

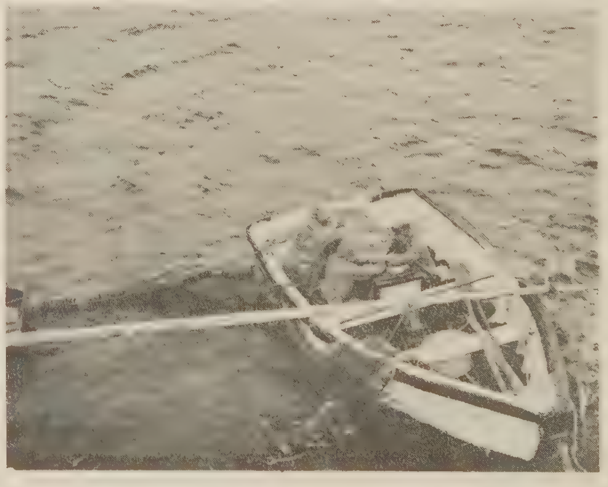

FIG. 9 - TAGGING HERRING, SOUTHEASTERN ALASKA, WINTER 1952/53.

The herring used for tagging were taken from the seine after the net had been dried up sufficiently to concentrate the fish. At this stage of hauling, the herring were confined in the fish bag, which rests between the vessel and the seine skiff. An outrigger pole was used to hold the seine skiff away from the side of the vessel, thereby

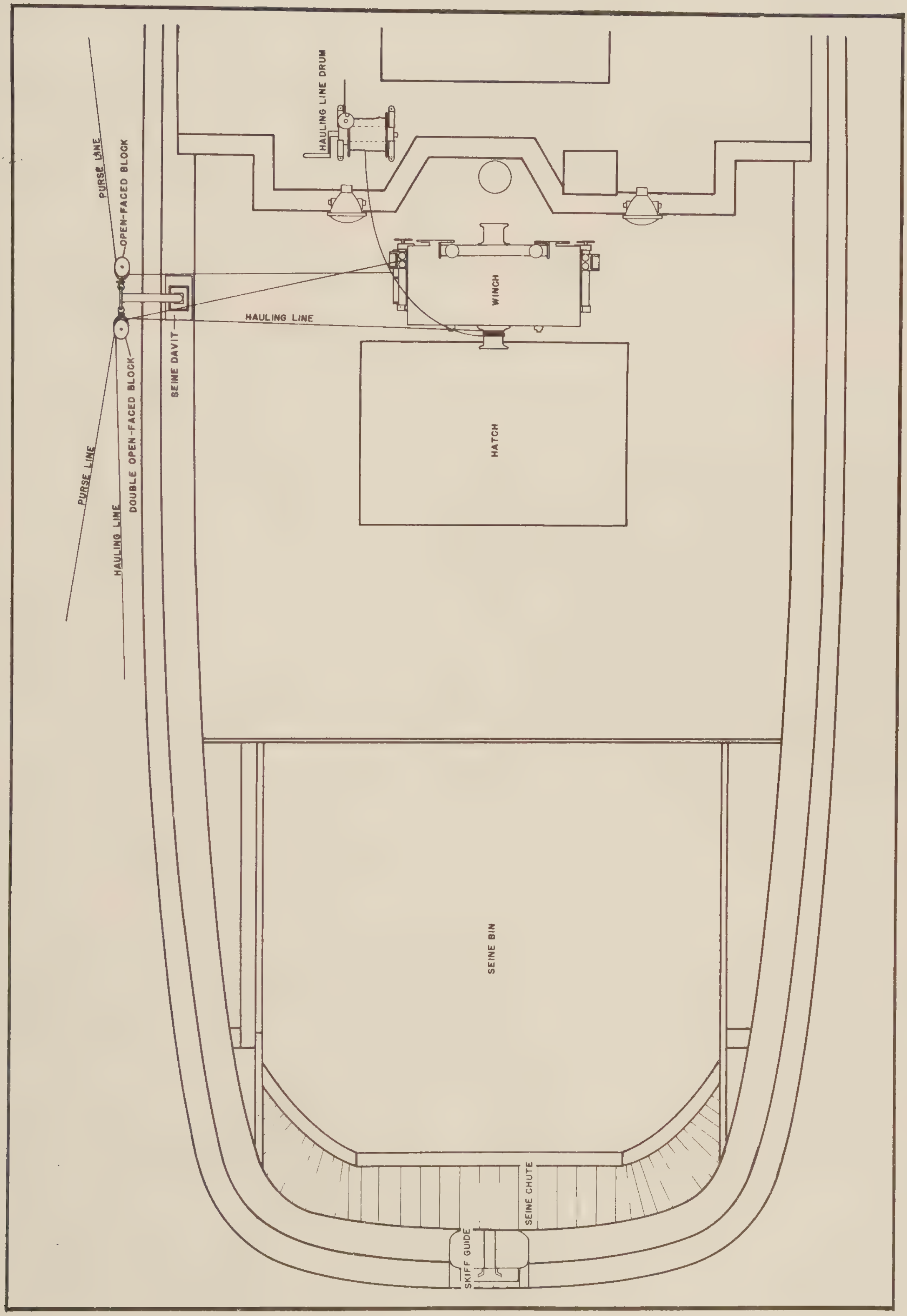
PURSE LINE
OPEN-FACED BLOCK
HAULING LINE DRUM
WINCH
HAULING LINE
SEINE DAVIT
DOUBLE OPEN-FACED BLOCK
PURSE LINE
HAULING LINE
HATCH
SEINE BIN
SEINE CHUTE
SKIFF GUIDE

FIG. 10 - AFTERDECK OF THE *JOHN N. COBB* AS MODIFIED FOR PURSE-SEINING.

preventing excessive crowding of the herring within the net. The general setup of the tagging procedure is shown in figure 9.

In the 1952/53 season, a total of eight tags were recovered from the Kendrick Bay tagging. These recoveries were made by the commercial seiners fishing in this bay shortly after the tags had been affixed. Since all recoveries came from Kendrick Bay, they do not furnish any information on migration. No tags from the Tongass Narrows tagging have been recovered. The possibility for the recovery of these tags will depend on whether or not these fish move into other areas where they are subject to capture by the reduction fishery.

The British Columbia fishery did not operate in the 1952/53 season because of price disagreements, so that the possibility of Canadian recoveries was lost for the winter of 1952/53.

PROSPECTS FOR FUTURE WINTER OPERATIONS

Although the explorations by the John N. Cobb and the commercial fleet did not result in finding numerous concentrations of herring, this by no means eliminates the future possibility of winter herring fishing in Southeastern Alaska. In adjacent British Columbia waters only limited concentrations of herring have been found, but these concentrations are so dense as to support a substantial reduction fishery.

FIG. 11 - LAUNCHING SEINE SKIFF FROM THE STERN OF THE JOHN N. COBB.

Ogden Channel in northern British Columbia contributed approximately 480,000 barrels to the British Columbia herring catch in the season of 1951/52. While Ogden Channel is approximately 7 miles long by 2 miles wide, the actual fishing ground was comprised of an area of about one square mile. Prospecting in other areas of the northern subdistrict has failed to reveal other localities with comparable concentrations of herring. Had Ogden Channel been overlooked in exploring these waters, it might have been concluded that herring were not abundant in this area.

There appears to be a similarity between Ogden Channel and Tongass Narrows in that both are congregating areas for prespawning herring schools. Tongass Narrows, which contained an enormous quantity of herring throughout the winter, was closed by regulation to fishing for reduction purposes. Had these fish congregated in some locality open to the fishery, the success of these operations would have been assured. With this situation, the only practical limitation on the size of the take would have been the ability of the reduction plants to handle the fish.

In other areas where concentrations of herring were available to the fishery, such as in Kendrick Bay, exceptionally good catches were made. The analysis of logbooks showed the average catch was approximately 600 barrels per set, compared to an average of approximately 150 barrels in the summer period of 1952.

A factor which contributed to the low catch by the commercial vessels was the inability of one of the reduction plants to handle the fish. As a result, much fishing time was lost by the two vessels fishing for this company. The captains of these vessels declared that they could easily have doubled their catch had the plant been able to unload their fish with normal efficiency.

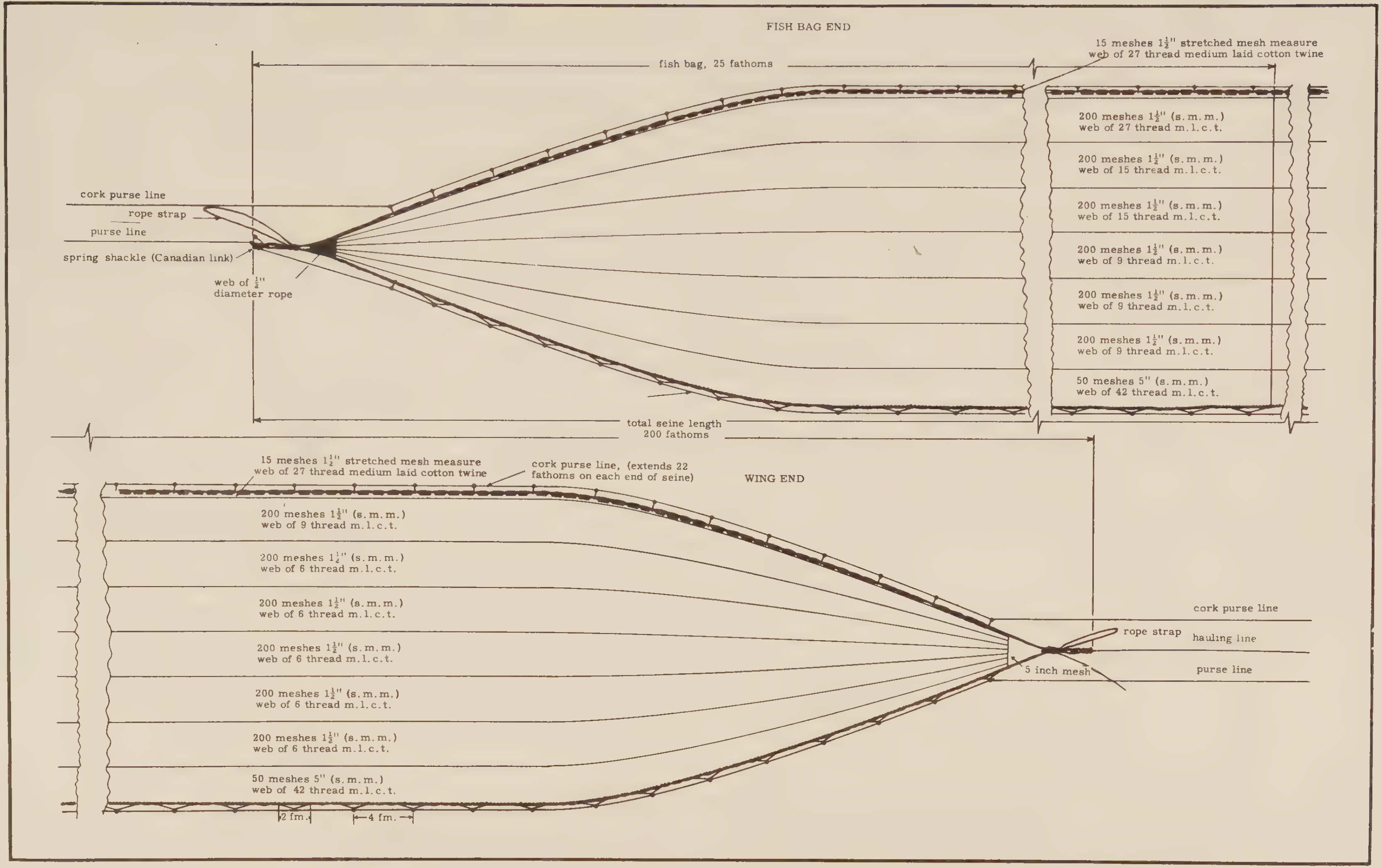
FISH BAG END
fish bag, 25 fathoms
15 meshes 1½" stretched mesh measure
web of 27 thread medium laid cotton twine
200 meshes 1½" (s.m.m.)
web of 27 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 15 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 15 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 9 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 9 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 9 thread m.l.c.t.
50 meshes 5" (s.m.m.)
web of 42 thread m.l.c.t.
cork purse line
rope strap
purse line
spring shackle (Canadian link)
web of ½" diameter rope
total seine length 200 fathoms
15 meshes 1½" stretched mesh measure
web of 27 thread medium laid cotton twine
cork purse line, (extends 22 fathoms on each end of seine)
WING END
200 meshes 1½" (s.m.m.)
web of 9 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 6 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 6 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 6 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 6 thread m.l.c.t.
200 meshes 1½" (s.m.m.)
web of 6 thread m.l.c.t.
50 meshes 5" (s.m.m.)
web of 42 thread m.l.c.t.
2 fm.
4 fm.
cork purse line
rope strap
hauling line
5 inch mesh
purse line

FIG. 12 - FISH BAG AND WING ENDS OF THE PURSE SEINE USED ON THE JOHN N. COBB IN HÉRRING EXPLORATION.

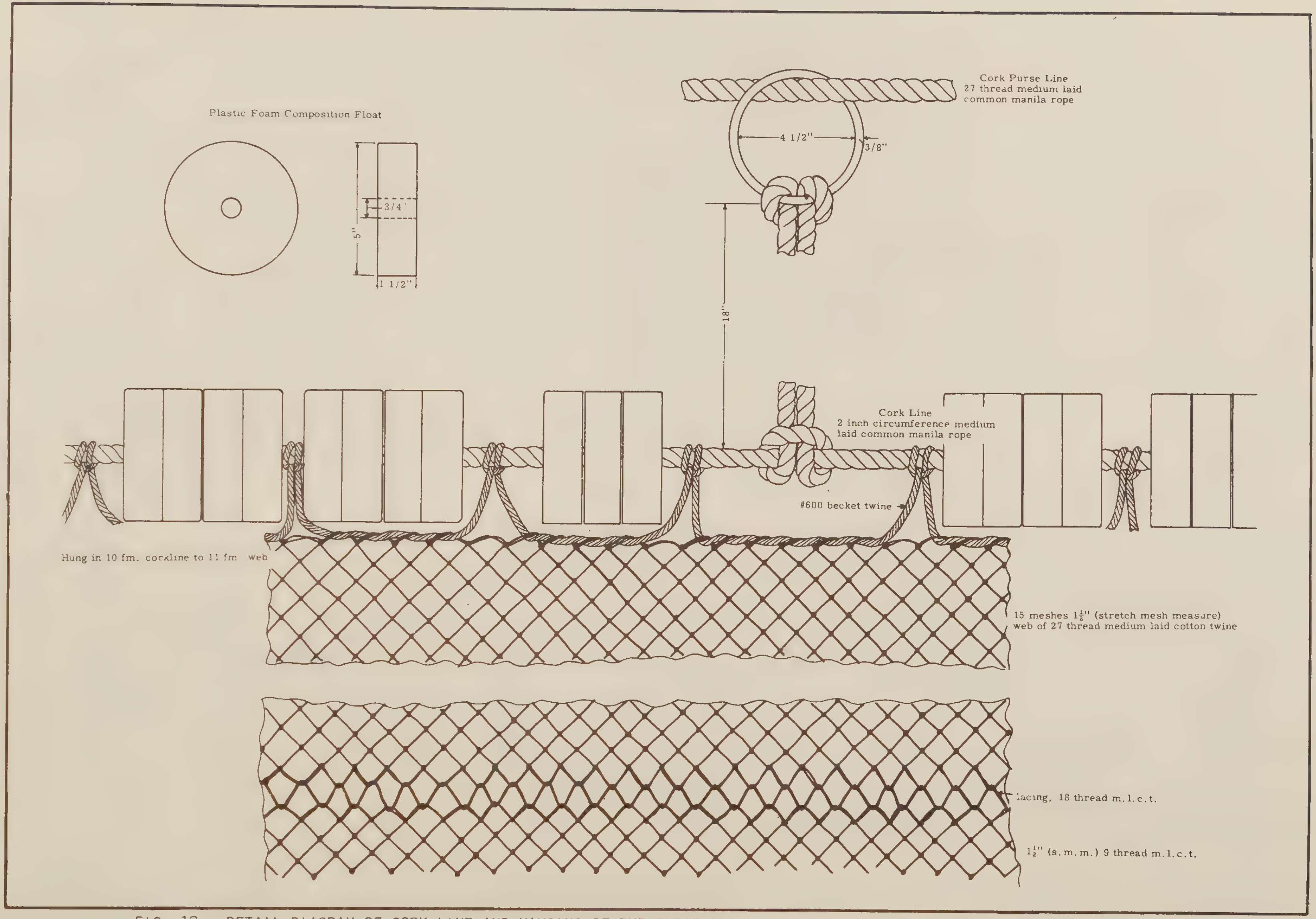
Plastic Foam Composition Float
3/4"
5"
1 1/2"
Cork Purse Line
27 thread medium laid
common manila rope
4 1/2"
3/8"
18"
Cork Line
2 inch circumference medium
laid common manila rope
#600 becket twine
Hung in 10 fm. corkline to 11 fm. web
15 meshes $1\frac{1}{2}$" (stretch mesh measure)
web of 27 thread medium laid cotton twine
lacing, 18 thread m.l.c.t.
$1\frac{1}{2}$" (s.m.m.) 9 thread m.l.c.t.

FIG. 13 - DETAIL DIAGRAM OF CORK LINE AND HANGING OF THE PURSE SEINE USED ON THE *JOHN N. COBB* IN HERRING EXPLORATION.

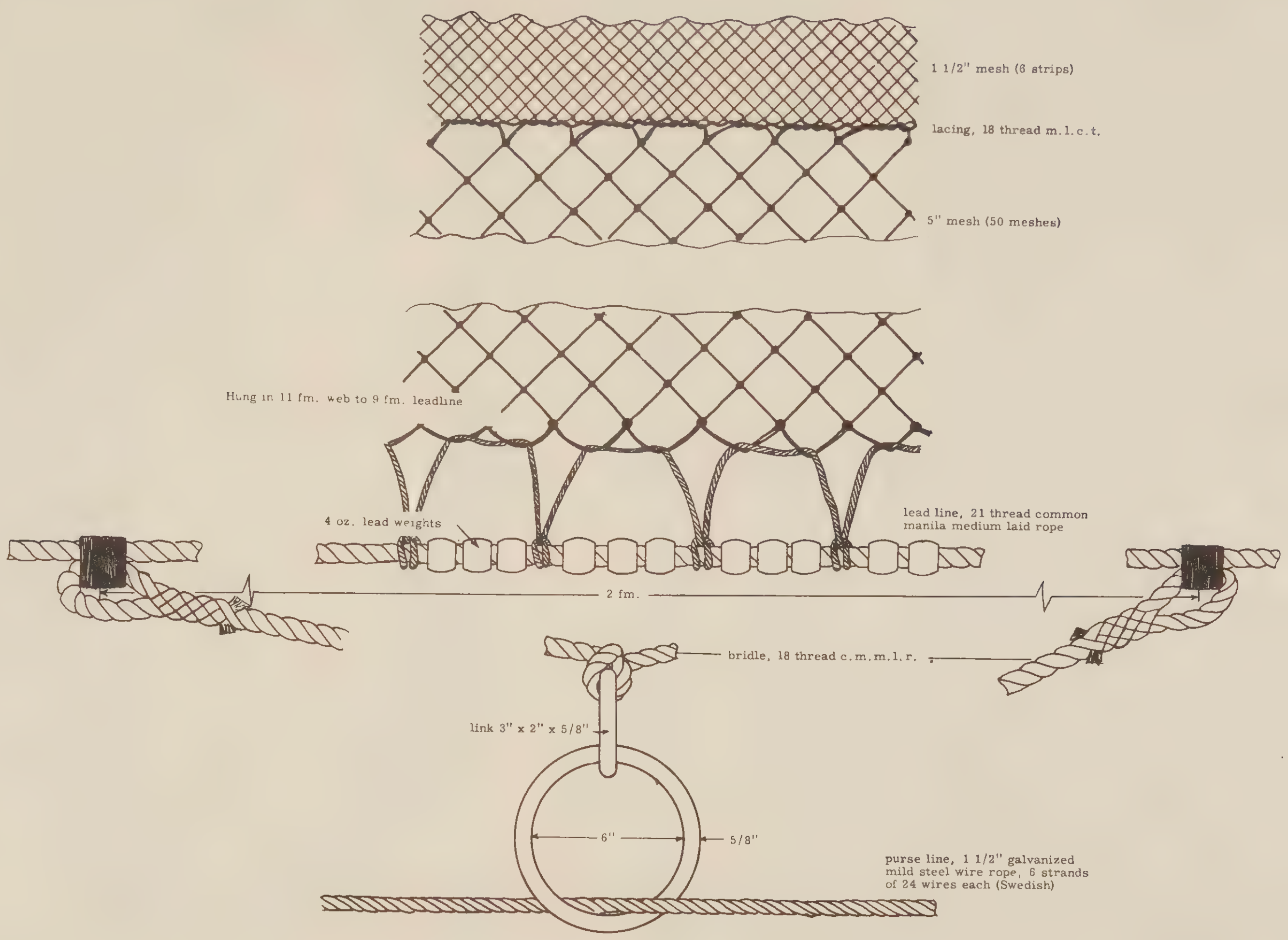
1 1/2" mesh (6 strips)
lacing, 18 thread m.l.c.t.
5" mesh (50 meshes)
Hung in 11 fm. web to 9 fm. leadline
4 oz. lead weights
lead line, 21 thread common manila medium laid rope
2 fm.
bridle, 18 thread c.m.m.l.r.
link 3" x 2" x 5/8"
6"
5/8"
purse line, 1 1/2" galvanized mild steel wire rope, 6 strands of 24 wires each (Swedish)

FIG. 14 - DETAIL DIAGRAM OF LEAD LINE AND HANGING OF THE PURSE SEINE USED ON THE JOHN N. COBB IN HERRING EXPLORATION.

In evaluating these results it should be remembered that the John N. Cobb was only one vessel attempting to cover a tremendous area, and that the commercial vessels were working at a different season of the year and in an area not previously exploited by the reduction fleet. It has been the experience of the Alaska herring fishery that success in the exploitation of new areas is seldom immediate but usually requires several years of exploration in which the fishermen learn the peculiarities of the fishing grounds.

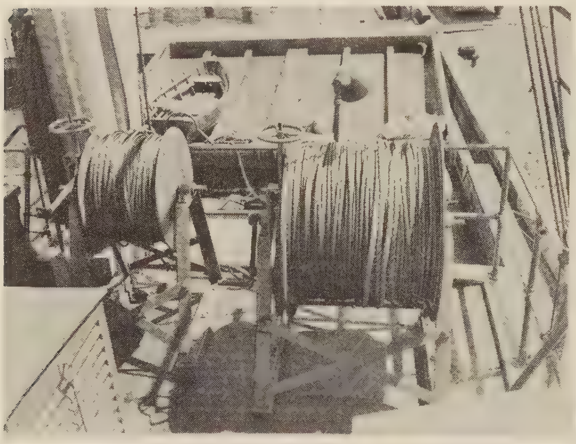

FIG. 15 - AFT HAULING- AND PURSE-LINE DRUMS OF ALASKA HERRING SEINER.

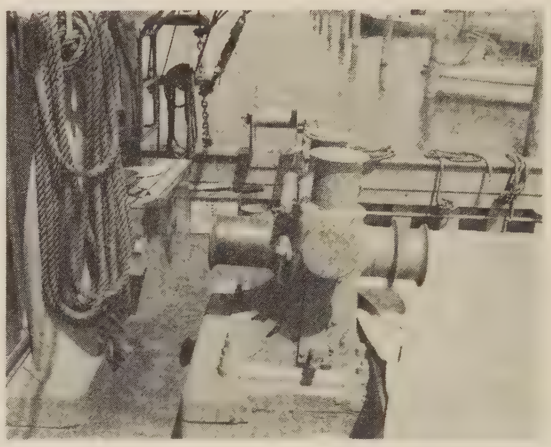

FIG. 16 - TYPICAL DECK WINCH ON ALASKA HERRING PURSE-SEINE VESSEL.

From the standpoint of herring abundance, the results of these explorations would seem to justify further efforts in winter fishing, at least in the Dixon Entrance area.

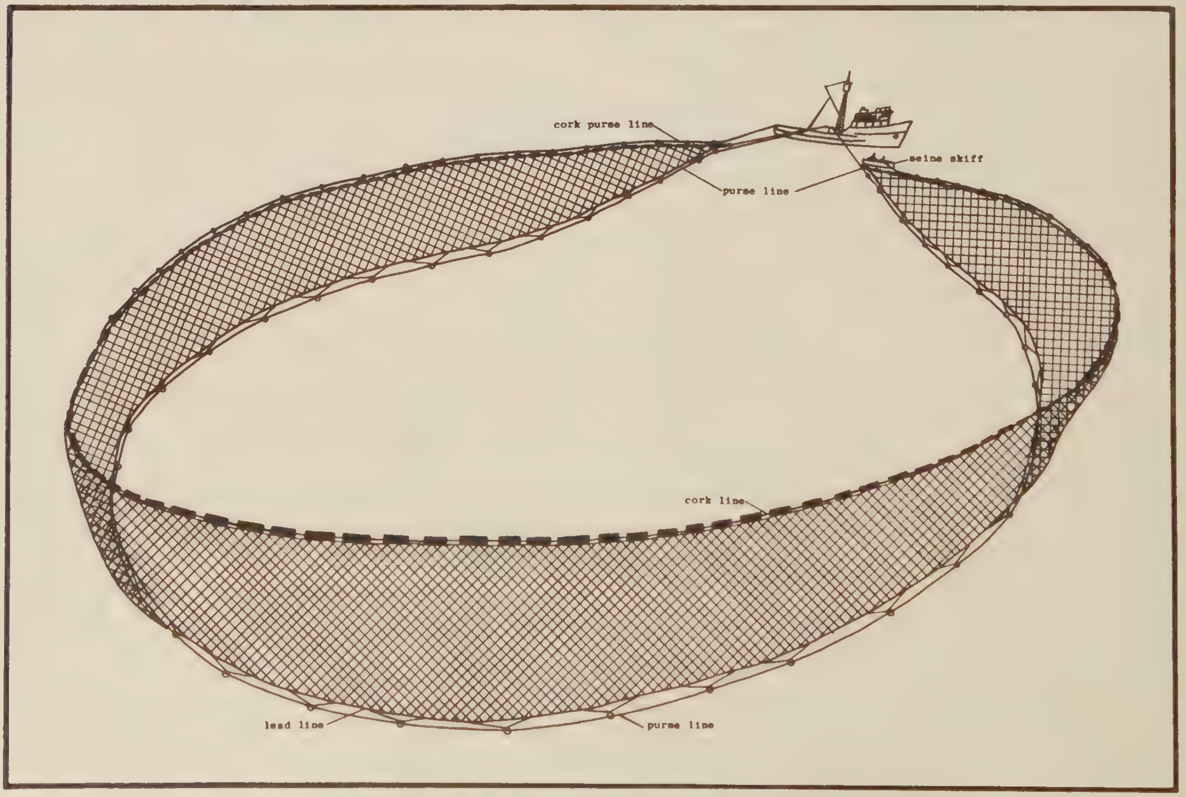

FIG. 17 - DIAGRAM OF ALASKA HERRING PURSE SEINE IN SET POSITION.

Whether or not such efforts will be made probably depends primarily on economic factors. The low oil yield of last winter, combined with the depressed state of the fish-oil market, probably resulted in financial losses for those companies concerned. It is doubtful that further commercial winter explorations can be anticipated until there is a substantial improvement in the market for fishery byproducts.

APPENDIX A - ALASKA HERRING-FISHING GEAR AND ITS OPERATION

MODIFICATIONS AND GEAR ON "JOHN N. COBB:" In order to adapt the John N. Cobb for work as a purse seiner, certain modifications were made to the afterdeck (figure 10). A net bin was constructed on the afterdeck and a seine chute was constructed across the stern to allow the seine to slide freely when making a set.

A skiff guide was built over the gunwale on the stern to facilitate launching the seine skiff.

On the starboard gunwale, a seine davit was installed opposite the winch, and a drum for the hauling line was mounted on the aft end of the deckhouse.

A standard tapered end-type Alaska herring purse seine of 200 fathoms length was used. Details of this seine are shown in figures 12, 13, and 14.

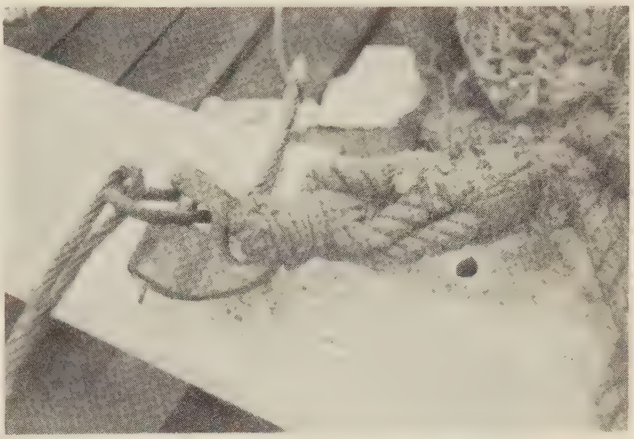

FIG. 18 - SPRING SHACKLE USED FOR ATTACHING BAG-END HAULING LINE AND PURSE LINE TO BAG END OF SEINE.

The use of rectangular-shaped nets with breast lines, described in other publications (Scofield 1951 and Murray 1952), has been discontinued by many of the Alaska herring seiners as they believe that any seine takes a tapered-end shape when being set and hauled. This taper is accomplished by gathering all the webbing to a piece of 5-inch web at the wing end and to a section of woven rope webbing at the fish-bag end. The webbing is hung to the cork line and lead line as shown in figures 13 and 14.

TYPICAL SEINING OPERATION: The foregoing describes the herring seining equipment used aboard the John N. Cobb. The gear arrangement on the typical herring seine vessel differs from that used on the John N. Cobb in the following respects:

1. The purse seine is stacked on a turntable rather than in a net bin. The turntable has a roller at the aft end to allow the net to roll freely over the stern of the vessel into the water. It is pivoted at its center and can be revolved.

2. Three drums (or reels) are used for taking in the purse lines and hauling lines. The drum for the aft hauling line and the drum for the purse line are mounted on the starboard aft corner of the deckhouse (figure 15). The drum for the forward hauling line and forward purse line is mounted on the port gunwale just opposite the winch (figure 16).

3. A winch with two gypsyheads is used for hauling the lines in. The aft gypsyhead is divided by a flange which provides two reeling surfaces. For convenience, the gypsyheads of the winch will be referred to as fore, middle, and aft (figure 16).

The operation of setting and retrieving the seine are given in the sequence of steps as follows:

1. The seine skiff is put over the stern and is towed close to the vessel by means of a painter (rope). The bag end of the seine is secured to the skiff by the

man, or sometimes two men, who operate the skiff. The skiff may or may not be powered.

2. When in suitable position in relation to the herring school, the painter is released from the deck of the vessel and a sea anchor is put out from the skiff. This slows the skiff and starts the seine off the turntable as the boat proceeds.

3. The vessel is steered in a circle around the school as the seine pays out from the turntable. The purse line comes off the outboard drum on the deckhouse, through the purse rings lined up in a trough on the port side of the turntable and into the water at the bottom of the seine.

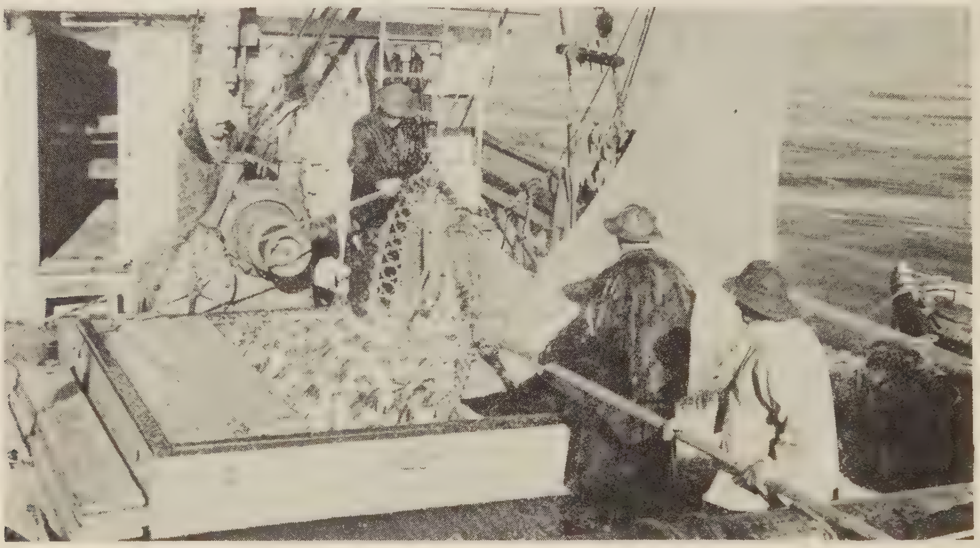

FIG. 19 - BRAILING HERRING FROM SEINE INTO HOLD OF VESSEL.

4. As the circle is nearly completed, the wing end of the seine goes off the turntable. This is attached by a shackle and swivel to the wing-end hauling line, which pays out from the inboard drum on the deckhouse.

5. A heaving line is thrown from the skiff to the vessel and the bag-end hauling line is pulled aboard.

6. At this point the following lines are hauled in simultaneously:

a. The forward hauling line, which is attached to the forward purse line and to the bag end of the seine by the spring shackle (figure 18) is taken in on the forward gypsyhead and wound on the drum at the port gunwale.

b. The aft purse line is taken in on the middle gypsyhead and wound on the outboard drum on the deckhouse.

c. The aft hauling line is taken in on the aft gypsyhead and wound on the inboard drum on the deckhouse.

d. The bag-end cork purse line is hauled by hand in the seine skiff and coiled there.

e. As soon as the aft hauling line is in, the wing-end cork purse line is hauled in on the aft gypsyhead and coiled on deck.

f. Pursing continues until all the purse rings are drawn up to the seine davit. A wire rope strap is then put through them and they are hoisted up and laid on deck.

7. The position of the turntable is then reversed so that the roller faces forward preparatory to taking the seine on board.

8. Starting with the wing end the seine is hauled aboard by means of a rope strap, which is wrapped around the body of the seine. It is hoisted by a single "whip" line which runs to the tip of the boom. In successive bights, the seine is hauled out of the water and lowered on to the turntable, where it is stacked in proper order for setting again.

9. "Strapping" is continued, crowding the fish into the fish-bag end of the net. When they are sufficiently concentrated, they are dipped out of the seine with the "brail" and spilled into the hold (figure 19).

10. When the fish have been removed, the remainder of the net is strapped aboard.

11. The turntable is turned about and the bag-end purse line is rewound from the port gunwale drum to the outboard drum on the deckhouse.

12. The purse line is threaded through the purse rings and attached by the spring shackle to the bag end of the seine preparatory to making a new net.

APPENDIX B - JOHN N. COBB FISHING LOG FOR CRUISE 14
(November 4 to December 19, 1952)

November 4-7: Cleared King County Dock at Seattle, Washington, and proceeded on routine trip to Ketchikan, Alaska. Entered Tongass Narrows at 0830 and observed large flocks of sea gulls apparently feeding on herring. Fish were noted on the echo sounder between 40 and 80 feet.

November 8: Arrived at Washington Bay. Spent day unloading salt, and loading purse seine and rigging gear.

November 9: Made a practice set of the purse seine in Washington Bay. Sounded Bay of Pillars, Tebenkof Bay, and Port Conclusion with the echo sounder. The only indication of herring was one small "pip" recorded on the echo sounder in Pillar Bay and a few scattered birds in Tebenkof Bay.

November 10: Sounded Port Armstrong and Port Walter and made run toward Cape Ommaney area. The sea was too rough for making herring observations in the Cape Ommaney-Larch Bay area so the region was bypassed.

One whale was seen at the mouth of Port Walter, but no indication of herring was obtained in the Port Conclusion-Port Walter or the Cape Ommaney area. No indication of herring was seen in the Murder Cove area although a few small birds were observed.

November 11: 0700-1200 lay at Tyee due to strong southeast wind and rain. 1300-1730 scouted and sounded Security Bay, Saginaw Bay, Keku Strait, and Kake area. Several gulls were seen in Security Bay and cormorants were observed on the north side of Saginaw Bay. One small pip recorded on the echo sounder while passing the northwest tip of Keku Island. The Service's vessel Crane reported that herring flippers were seen in Big John Bay on the evening of this date.

November 12: Sounded Kake and upper Keku Strait area. Sounded Port Camden to about two-thirds the way to the head of the bay. No evidence of herring was found in the Keku Strait-Kake area but large schools were recorded by the echo sounder near the mouth of and inside Port Camden. These large schools appeared over depressions or "gullies" in the bottom. The largest of these schools was lying over a sharp depression at depths of from 180 feet to near the bottom of the depression at 260 feet. This school was approximately 3 miles inward from the mouth of the bay. Numerous small pips were recorded from near the surface to the bottom in the outer one-half of the bay. Small herring were brought to the surface near midnight on November 12 by playing the searchlight and a submarine light on the water. Several herring taken in dip nets proved to be one- and two-year-old fish.

November 13: Continued sounding in Port Camden and Keku Strait areas. Herring in Port Camden appeared deeper and even more densely packed over depressions in the bottom than on November 12. Left area at 1225 for Seymour Canal. Echo sounder recorded several small pips of feed between Port McCartney and Turnabout Island. Entered Seymour Canal at 1525; evidence of small amounts of feed showed on echo sounder at 60- to 80-foot depths, numerous sea gulls, several whales, and one hair seal were seen near the entrance to Mole Harbor in Seymour Canal. Anchored for night in Mole Harbor. Night observations revealed no herring.

November 14: Sounded Seymour Canal from Mole Harbor to Windfall Harbor including area around Dorn Island and Tiedeman Island. A scattering of small traces were recorded in Mole Harbor from the surface to 80 feet. A murre was seen with a fish of about 2 inches in length, and one small fish (presumably herring) was seen flipping. Scattered birds were seen working the entire bay. In the vicinity of Tiedeman Island and Windfall Harbor, many small birds and numerous whales were seen but no evidence of herring, other than small pips at various depths on the echo-sounder tape. Launched seine skiff and prepared for possible night set at 1500. At 1735, in the mouth of Pleasant Bay, a large dark trace appeared on the sounder tape at 40- to 80-foot depths. This area was drifted, sounding until 1945. The sounder showed numerous small pips which seemed to be fish rising toward the surface. Another fairly good-sized school was recorded at 1815 in the stratum 20 to 76 feet.

November 15: Left Seymour Canal. Sounded area on west side of The Brothers Islands, the right arm of Pybus Bay, and the right arm of Gambier Bay. A few small pips were recorded near The Brothers Islands and in the right arm of Gambier Bay. Otherwise no sign of herring was seen in this area.

November 16: Left Gambier Bay for Petersburg. Small pips of feed were encountered in the vicinity of Sukoi Island. Fair to good showings of feed were recorded at the north entrance to Wrangell Narrows. Arrived at Petersburg at 1625.

November 17: Left Petersburg at 0900 for Windham Bay. A light and narrow band was recorded on the echo sounder at 180 feet just inside of Sunset Island near Windham Bay. Soundings in Windham Bay showed no evidence of herring. Upon rechecking the Sunset Island area the light narrow tracing was again picked up. This tracing continued for 10 miles as the vessel proceeded up Stephens Passage, rising gradually as darkness fell until it ended at 1630 off Point Astley. A herring jig was tried at the depth of this recording with no results. Anchored at 2005 in southeastern end of Gilbert Bay.

November 18: Sounded in Gilbert Bay and Port Snettisham and then proceeded to Juneau. Some very small pips were recorded at about 30 feet near Whiting River in Gilbert Bay. No other indications were seen in upper Stephens Passage or Port Snettisham. Arrived at Juneau at 1248.

November 19: Left Juneau at 0900. Sounded Gastineau Channel and westward in Stephens Passage to Barlow Cove. A scattering of small pips was recorded off the SE. tip of Douglas Island (Point Hilda) from 20 feet to the bottom at 240 feet. Several gulls were observed upon entering Barlow Cove at 1345. The cove was sounded until 1730, but only a few scattered small pips were recorded.

November 20: Raised anchor in Barlow Cove and sounded out of cove heading for Lisianski Inlet. At 1145 observed five small pips at 20 fathoms between Porpoise Islands and Hoonah in Icy Strait. Sounded between Eagle Point and Point Adolphus, recording only a few small pips from the surface to the 120-foot depth. Ran SE. in Lisianski Inlet to Pelican City. A group of sea gulls and a sea lion were observed at the junction of Lisianski Strait and Inlet but no tracings were recorded on the echo sounder. A large flock of sea gulls sitting on the water near Pelican City was investigated but no pips were recorded on the sounder.

November 21: Left Pelican City, sounding toward the head of the inlet. Found one school of herring at 1½ miles north of Soloma Point. Made preparation for a set. Sounded to the head of the inlet with negative results. Herring were found again in the vicinity of Soloma Point in two schools estimated by Fishing Captain Hansen to be about 200 barrels each. Two herring were caught on the jig gear. These schools were too close to the beach to make a purse-seine set on them. Near Miner Island several large brown spots indicating schools of fish were observed. Large flocks of gulls were seen working here and several were seen catching fish. Upon sounding over these schools, large light tracings were recorded from the surface to the 80-foot depth. This area was fished with the herring jig and approximately 10 young rockfish about 3 to 4 inches in length were caught. These fish were staying close to the creek mouth.

November 22: Sounded from Lisianski Inlet to Idaho Inlet finding no evidence of herring on the echo sounder. At 1245 a large group of gulls was investigated in Idaho Inlet. A fairly large group of small pips was recorded at 20 feet to 40 feet, but the jig gear failed to catch any herring. Continued sounding and investigating bird groups in Idaho Inlet until 1554. No evidence of commercial quantities of herring was found here.

November 23: Left Hoonah at 0930 and sounded Port Frederick, finding a few scattered pips of feed distributed from the surface to the 400-foot depth, but otherwise no sign of herring. Left Port Frederick for Freshwater Bay at 1300. Entered Freshwater Bay at 1710 and sounded in the vicinity of Wachusett Cove and Pavlof Harbor finding no indications of birds or herring.

November 24: 0800. Started sounding out of Freshwater Bay to Tenakee Inlet; no sign of herring. Sounded in area off the Superior Packing Co. cannery, finding no indication of feed and no birds. At 1030 the Bendix echo sounder stopped operating due to a burned out motor; Juneau was contacted by radio for parts and sounding was continued with the Submarine Signal Co. flasher-type echo sounder. Tenakee Inlet was investigated to a point approximately 7 miles from the head of the inlet. At 1635 a small flock of gulls and murres was seen working in the tide rip 3 miles west of Long Bay area, Tenakee Inlet. Anchored near Long Bay at 1930. The searchlight was played upon the water at night but failed to raise any herring.

November 25: Continued observations in Tenakee Inlet until 1135 with negative results and then left for Hawk Inlet. Investigated Hawk Inlet from 1335 to 1535 finding several hair seals, and large flocks of scoters, ducks, and gulls in the vicinity of the river flats, but no other indications of herring either on the surface or on the echo sounder. Proceeded toward Juneau to repair echo sounder. Anchored in Barlow Cove at 1850.

November 26: Sounded from Barlow Cove to Juneau, finding no indications of herring schools. Several whales were noticed in the vicinity of Point Tantallon.

November 27, 28, and 29: Waited for parts to repair echo sounder at Juneau.

November 30: While running, sounded Peril Strait, Salisbury Sound, and Neva Strait, anchoring in Nakwasina Passage at 1640.

December 1: Sounded Katlian Bay. Two small tracings were recorded at a depth of 220 feet and small fish were seen surfacing among the rocks and small islands in the north end of the bay. Sounded past Sitka to Silver Bay entering the bay at 1150. Many sea lions and a whale were observed at the mouth of the bay. Large schools of herring were recorded lying on the bottom at the 220-foot depth at the entrance to the bay.

Tied up at Sitka at 1328 and returned to Silver Bay at 1700. A large body of fish was picked up again at the entrance to the bay. This school was about two-thirds of a mile long by one-third of a mile wide, lying deep, mostly just off the bottom at the 250-foot depth. At about 1900, good-size herring were heard flipping all about the boat, but the echo sounder showed the main body of fish to be lying near the bottom. Fishing Captain Hansen said he had never heard so many flippers nor seen such a compact concentration of herring in any area. A purse-seine set was made at 1955, but the school was missed and only a few small herring were caught. The school was either too deep or sounded as the set was made. Net back aboard at 2145.

December 2: Left Sitka, running southeasterly down outside coast of Baranof Island. Sounded Larch Bay from 1600 to 1625 finding no indications of herring on the echo sounder. The sea was too rough to work the area well. Anchored in Port Armstrong at 1800.

December 3: Remained in Port Armstrong due to storm warnings and winds to gale force in Chatham Strait.

December 4: Left Port Armstrong for the Warren Island area. Sounded the Warren Channel, Bocas de Finas, Gulf of Esquibel, and Arriage Passage area including Steamboat Bay and the east side of St. Joseph Island. These areas were devoid of signs of herring except for a few scattered birds and three whales seen in the vicinity of Noyes Island.

December 5: Investigated Davidson Inlet and Tokeen Bay with negative results. Only a very few scattered gulls were seen. Cleared Davidson for Ketchikan with sounder operating.

December 6: Proceeded to Wards Cove in Tongass Narrows to observe herring reduction there. Sounded Narrows en route to and from Wards Cove, finding no schools of herring. Sounded Tongass Narrows near Ketchikan from 1610 to 1850. Large schools were recorded, apparently beginning to rise from the bottom at about 1700. At 1742 to 1752 a nearly solid school of herring was found extending from the Coast Guard Base to the Northern Machine Works, a distance of $1\frac{1}{2}$ miles on the Ketchikan waterfront. This school extended from the 20- to about the 80-foot depth.

December 7: Left Ketchikan for Kendrick Bay. Sounded south arm and short arm of Kendrick Bay and McLean Arm. Many birds, sea lions, and a few hair seals were seen in Kendrick Bay, and schools of fish were recorded near the bottom in both Kendrick Bay and McLean Arm. At 2100 the sounder showed a school of fish at the 20- to 40-foot depth in McLean Arm. These were apparently rising. Some of these fish were drawn up to light and were seen to be small.

December 8: Sounded again in McLean Arm and Kendrick Bay. Fish were recorded by the sounder in both places near the bottom. Anchored in Kendrick Bay at 1030 to await darkness and the rising of the herring. Started sounding again at 1700 and set on large school 20 to 80 feet deep. Pursed seine, catching approximately 1500 barrels of small herring.

December 9: Spent day tagging herring and overhauling gear.

December 10: Left Kendrick Bay for Carroll Inlet. Sounded Carroll Inlet to head, finding only a few small pips on meter at the entrance and several sea gulls and murres near Gnat Cove. Anchored near Spit Cove at 1512. Raised anchor at 1845 and sounded toward mouth of the inlet.

December 11: Sounded out of Carroll Inlet and found no more indication of herring. Sounded George Inlet to vicinity of Libby's cannery. In this area several small pips near the surface and large dark tracings of schools of herring on the bottom at 200 feet were recorded. Left area for Ketchikan at 1000. Tied up at Ketchikan for mail and motorboat repairs. Left for Washington Bay at 1610.

December 12: Arrived at Washington Bay and spent day repairing and salting down purse seine.

December 13: Finished repairing and storing net.

December 14: Left Washington Bay for Ketchikan.

December 15: 0455. Arrived at Ketchikan and tied up at Tongass Trading dock. The echo sounder and flippers indicated herring just off the dock. A set was made on these with the lampara net and seine skiff to catch herring for tagging. Spent the day tagging herring.

December 16: Tagged herring from 0830 to 1100 and then left for Metlakahtla to consult with personnel of Oceanic Fisheries Co. on their reduction barge there.

December 16-19: Routine run to Seattle, arriving at Fish and Wildlife Service's dock at 1500, December 19.

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LITERATURE CITED

HART, JOHN LAWSON, TESTER, ALBERT L.; BEALL, DESMOND; AND TULLY, JOHN P.
1940. PROXIMATE ANALYSIS OF BRITISH COLUMBIA HERRING IN RELATION TO SEASON AND CONDITION FACTOR. JOURNAL FISHERIES RESEARCH BOARD OF CANADA, VOL. IV, NO. 5, PP. 478-490.

HOURSTON, ALAN S.
1953. ESTIMATION OF HERRING POPULATION SIZE BY MEANS OF ECHO-SOUNDER TRACINGS AND ITS APPLICATION TO HERRING RESEARCH. FISHERIES RESEARCH BOARD OF CANADA, PACIFIC BIOLOGICAL STATION, NANAIMO, B. C., CIRCULAR NO. 26, FEBRUARY (1953).

MURRAY, JOHN J.
1952. REPORT ON 1951 BLUEFIN-TUNA FISHING IN THE GULF OF MAINE. COMMERCIAL FISHERIES REVIEW, VOL. 14, NO. 3, PP. 1-19, MARCH 1952.

SCOFIELD, W. L.
1951. PURSE SEINE AND OTHER ROUNDHAUL NETS IN CALIFORNIA. FISH. BULLETIN NO. 81, 1951. STATE OF CALIFORNIA DEPT. OF FISH AND GAME, BUREAU OF MARINE FISHERIES.

* * *

SMALL FRY ARE IMPORTANT

Today's children are tomorrow's customers. If they are trained to like fish and shellfish when they are young, it is likely that they will acquire a fondness for products-of-the-sea that will carry on when they later become heads of families. This fact was well confirmed in tests of the eating habits of men in the Armed Forces during World War II.

SCHOOLS ARE A MARKET FOR FISH.

Until a few years ago there was a widespread feeling that children did not like fish and would not eat it at school. Actual tests in schools however, have proven that if fish (or shellfish) is prepared properly and served attractively, school children will not only eat it but will acquire a liking for it.

Fish-cookery demonstrations by home economists of the Educational and Market Development Section of the U. S. Fish and Wildlife Service for school lunchroom supervisors, managers, and cooks constitute a substantial part of the educational program to get the children to eat and like fishery products. In every one of the 26 states where this program has been given so far, fishery products are now served more often and enjoyed by more children. As a result of this the schools are buying more fish.

The fish-cookery demonstration program of the Service is conducted in cooperation with the different state departments of education. To date, 21 of the 26 states east of the Mississippi River have had statewide programs for their school lunchroom personnel. Louisiana and Minnesota have also been covered. In several of the Plains States and in the three Pacific Coast States, the Service has presented several demonstrations but not on an extensive basis. This school year the program is being conducted in Iowa, Wisconsin, Michigan, Oklahoma, Pennsylvania, and West Virginia.

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REPRODUCTIVE CYCLE IN CYPRINA ISLANDICA

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Cyprina (Arctica) *islandica* is a clam closely resembling in general appearance the more common species, *Venus mercenaria.* Externally it differs from the latter by having a shaggy, black periostracum which covers the shell. Formerly it was considered to be exclusively a European species but later it was found to be widely distributed on both sides of the North Atlantic. In Europe it ranges from the coasts of England and Norway to the Arctic, while on our Atlantic Coast it is found as far south as Cape Hatteras. However, since it is a cold water species, it is not very abundant south of New England.

A review of the literature shows that many aspects of the biology of *Cyprina islandica* have never been studied. According to Jørgensen (1946) practically nothing is known about the reproduction of this species and, therefore, virtually no literature exists on the subject. Lack of knowledge of the biology of *C. islandica* of our Atlantic Coast is probably due to the difficulty of collecting these clams because they live comparatively far from shore and in deep water. Moreover, since until recently they were not caught commercially, the specimens could not be readily obtained from fishermen.

The situation was changed in 1943 when, in an effort to increase war-time production of sea food, an extensive fishery of *C. islandica* was developed in the waters of Rhode Island and Massachusetts. Since then, samples of these clams have been more easily obtainable. As the fishery expanded and the clams began to appear as a canned product, and in fresh condition, the U. S. Food and Drug Administration in 1944 officially accepted "ocean quahog" as the common name for *C. islandica* (Rhode Island Report, 1945). In this article, for the sake of brevity, we shall call them clams.

Since the beginning of the war-time intensive fishery, new beds of the clams have been discovered. As a rule, these beds are located at a depth ranging from 70 to 120 feet, and are usually confined to either sand and mud or sticky mud (Arcisz and Sandholzer, 1947). Samples of the clams for our studies were collected from such beds located off Point Judith, Rhode Island in approximately 100–120 feet of water. They were collected often enough to record any significant changes in the conditions of the gonads. The clams constituting the samples were adults, several years old, and averaged 3½ to 4 inches in length.

The lack of instruments prevented us from recording the temperature of the water directly over the beds at the time the samples were collected. Fortunately, information on the seasonal temperature changes in that general area is available from the data of Merriman and Warfel (1948), who recorded the bottom temperatures at monthly intervals between September, 1943 and May, 1946 in the area near Point Judith. Because of the proximity of the localities where these temperatures were recorded to our clam beds and because of the strong tidal movements in that general area, it is thought that there should be no pronounced local temperature differences.

Merriman and Warfel (1948) also gave data for bottom salinity of the same general region for the same period. Generally, the salinity was quite steadily maintained between 31.0 and 32.8 p.p.t., suggesting that this is an optimum salinity range for the existence and propagation of *C. islandica.*

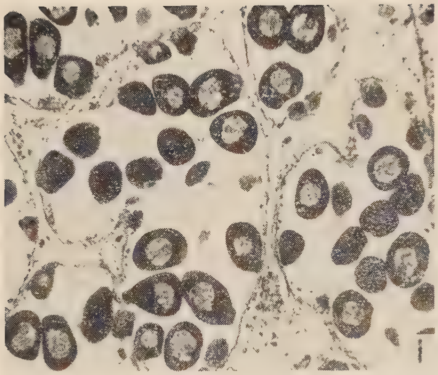
In studying the seasonal gonadal changes of *C. islandica* two approaches were used. The first consisted in histological studies of the material, which led to accurate determination of the condition of the gonads of each individual. Later on this information was used for the second, the statistical, approach, which gave us a quantitative conception of the successive changes in the gonad development during the year and of the progress of spawning during the season. The histological material will be discussed first, while the quantitative data and their analyses will be presented later and summarized in Tables I and II and Figure 13. Figure 13 was made the last figure of the article because of the convenience of not disturbing the continuity of the photomicrographs constituting Figures 1–12 inclusive.

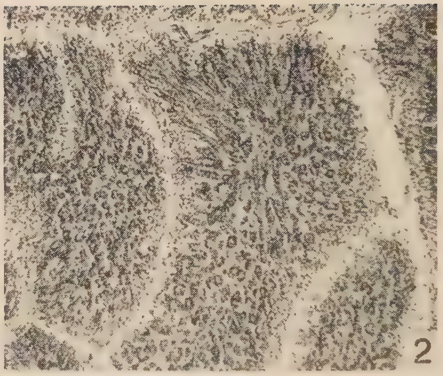
We may begin by considering the condition of the gonads of *C. islandica* just before the beginning of spawning. During the period of our studies this condition was reached by the end of June or early in July, when the temperature was near 13.0° C. Ripe female gonads were characterized at that time by extended follicles containing almost exclusively large, ripe ovocytes (Fig. 1). The walls of the follicles were touching each other, thus leaving virtually no space for the vesicular connective tissue. In males ripe spermatozoa predominated, occupying the largest portion of the follicular spaces, while cells of early stages of spermatogenesis were few in number and were confined to the area near the follicular walls (Fig. 2).

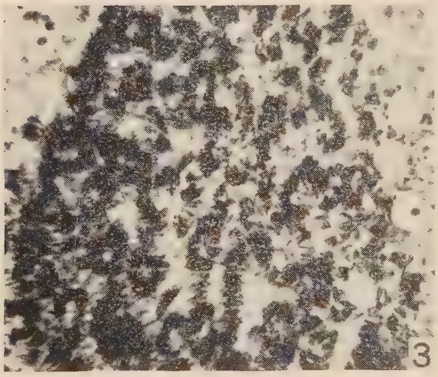
Even a superficial study of the gonads of ripe males often showed masses of "packed" spermatozoa, a condition caused by the arrangement of spermatozoa in the follicles in such a way that their heads were "packed" together creating the impression of a dense band (Fig. 3). A similar phenomenon was observed in *V. mercenaria* (Loosanoff, 1937a, 1937b) and several other lamellibranchs.

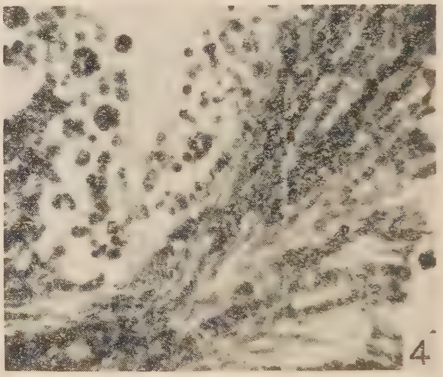
In addition to normal sex cells the follicles of many males also contained numerous multi-celled spherical dark bodies which were usually closer to the periphery of the follicles than to their centers (Fig. 4). Detailed examination of these bodies showed that they were cells of atypical spermatogenesis, noticed by Loosanoff (1937a) in *Venus mercenaria* and described by Coe and Turner (1938) in *Mya arenaria.* These cells apparently develop from the same type of spermatogonia as the normal ones but behave in a strikingly different way, undergoing several nuclear divisions, while still surrounded by the original mass of cytoplasm contained within the same cell membrane. Such abnormal bodies may contain from two to 16 nuclei (Fig. 5). It appears, as was noticed by Coe and Turner (1938), that in some cases such groups of nuclei may break apart and continue further individual development finally reaching the stage of spermatozoa. More often, however, they become pycnotic and are quickly cytolyzed.

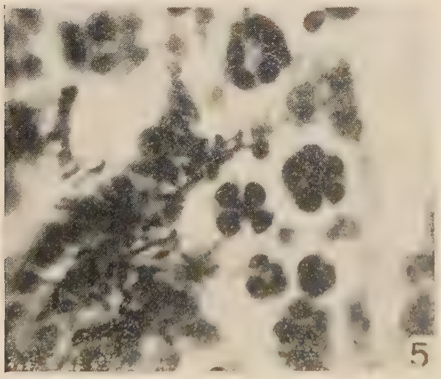
As is usual with lamellibranchs (Nelson, 1928a; Loosanoff, 1937b; Loosanoff, 1942), the entire population of *C. islandica* does not reach ripeness at the same time. We estimate that in the case of these clams only approximately 75 per cent were











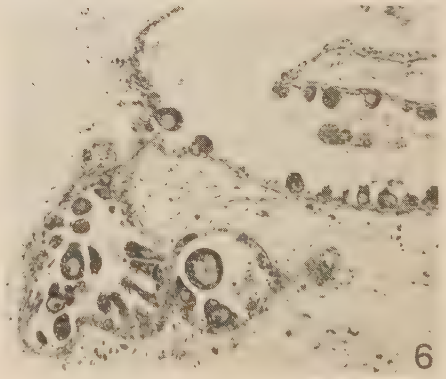


FIGURE 1. Gonad of ripe female. × 112.

FIGURE 2. Gonad of ripe male containing masses of spermatozoa ready to be discharged. × 112.

FIGURE 3. Section of male gonad showing "packed" spermatozoa. × 475.

FIGURE 4. Cells of atypical spermatogenesis occupying the periphery of a follicle containing ripe spermatozoa. × 475.

FIGURE 5. Different groups of cells (spherical) of atypical spermatogenesis. Normal spermatozoa are also present. × 1100.

FIGURE 6. Gonad of female in advanced stages of spawning. × 112.

TABLE I

Frequencies of occurrence of clams in different stages of sexual development at different dates between March 22 and November 1. Stage A: some ripe cells but generally unripe; Stage B: ripe but had not begun to spawn; Stage C: partly spawned; Stage D: completely spawned

Stages	Dates																
	3–22	4–5	4–19	5–3	5–17	5–31	6–14	6–28	7–12	7–26	8–9	8–23	9–6	9–20	10–4	10–18	11–1
A	10	7	8		3	4		5		0	0	0	0	0	0	0	0
B	3	2	2		1	3		13		5	4	8	6	1	0	0	0
C	0	0	0		0	0		2		3	4	10	12	6	3	8	1
D	0	0	0		0	0		0		0	0	1	3	6	4	9	5
Total	13	9	10		4	7		20		8	8	19	21	13	7	17	6

ripe or nearly ripe at the beginning of the spawning season. In the others the gonads still contained a large number of unripe cells. These conditions were especially noticeable in retarded males, the gonads of which contained predominantly the cells of early stages of spermatogenesis, although a few sperm were already present in the centers of some of the follicles.

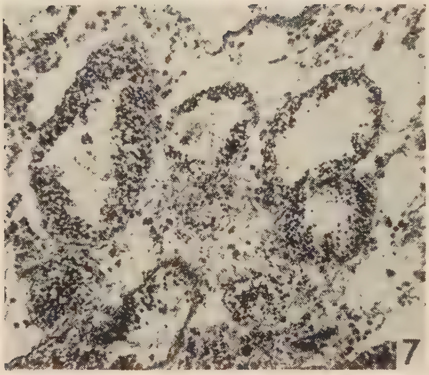
Judging by the condition of the gonads of both sexes, spawning began late in June or early in July when the water temperature over the beds was about 13.5° C. This temperature closely approached that reported by Nelson (1928b) for two other deep-water lamellibranchs, Astarte and Venericardium, which spawn near 12.0° C. Towards the end of July between 30 and 40 per cent of the clams were partly spawned but, as a rule, the quantity of spawn discharged remained small even then, thus indicating that a heavier and more general spawning was yet to follow. This was true because during August spawning continued, involving larger groups of the clam population, and toward the end of this month individuals of both sexes in advanced spawning conditions were becoming more common. In the females constituting this group the gonadal follicles were either empty or contained a few undischarged eggs (Fig. 6). In the males, most of the content of the follicles was discharged but the abnormal cells were still retained in large numbers, being confined to the periphery of the follicles where they were found among the normal cells

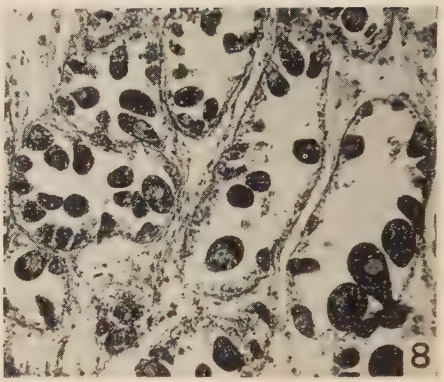
TABLE II

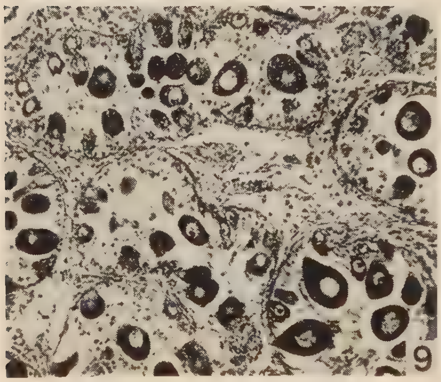
Cumulative percentage of clams at different stages of sexual development between March 22 and November 1. Stages as defined in Table I

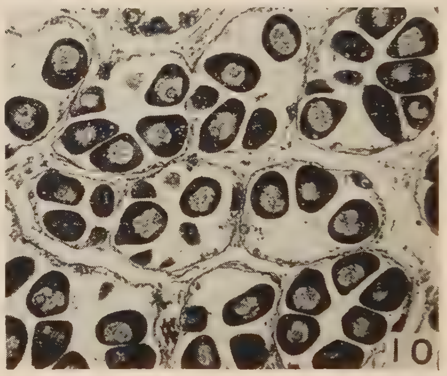
Stages	Dates																
	3–22	4–5	4–19	5–3	5–17	5–31	6–14	6–28	7–12	7–26	8–9	8–23	9–6	9–20	10–4	10–18	11–1
B + C + D	23.1	22.2	20.0		25.0	42.9		75.0		100	100	100	100	100	100	100	100
C + D	0	0	0		0	0		10.0		37.5	50.0	57.9	71.4	92.3	100	100	100
D	0	0	0		0	0		0		0	0	5.3	14.3	46.2	57.1	52.9	83.3
B + C + D (Adjusted*)	0	0	0		0	20.0		68.8		100	100	100	100	100	100	100	100

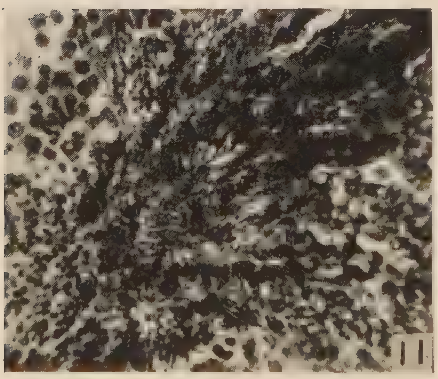
* Per cent in Stages B + C + D after subtraction of 20 per cent of sample size from Stage B and from total.











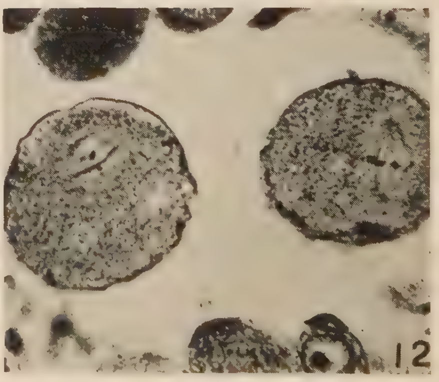


FIGURE 7. Almost empty follicles of male in advanced stages of spawning. × 112.

FIGURE 8. Female gonad in late October still containing some old ovocytes but also forming new ones to be discharged next year. × 112.

FIGURE 9. Female gonad in December showing largely small growing ovocytes, but also containing some that are morphologically ripe. × 112.

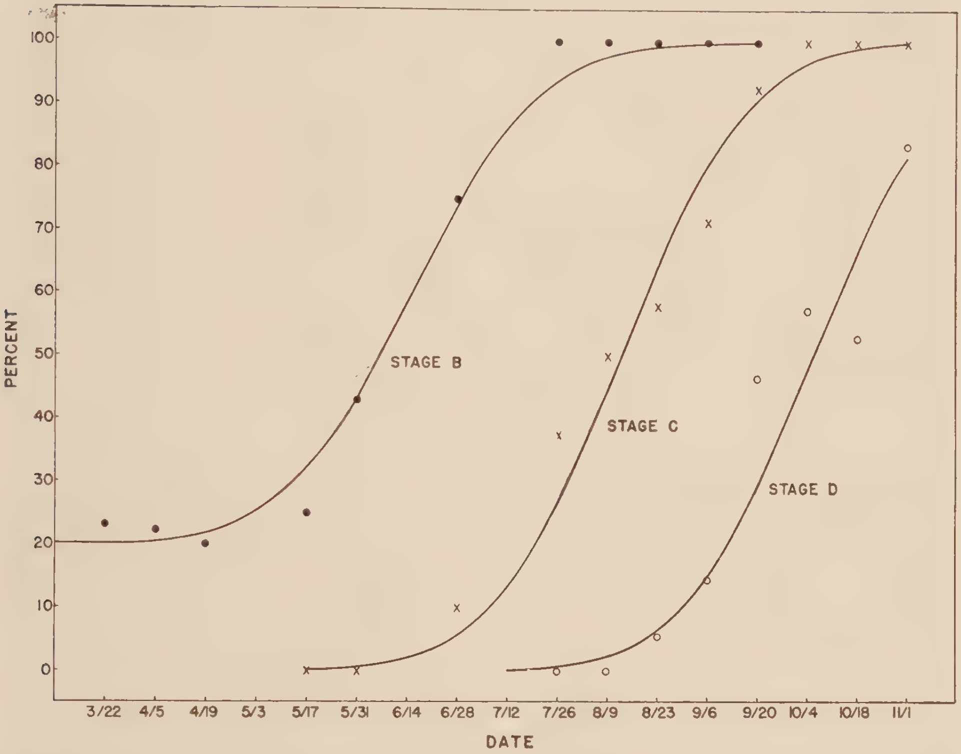


FIGURE 13. Percentage of clams in successive stages of sexual maturity at different times of the year. Stage B: ripe but had not begun to spawn; Stage C: partly spawned; Stage D: completely spawned. Additional explanation in text.

in earlier stages of development (Fig. 7). The emptied follicles were not contracted but remained distended, as was noticed for *V. mercenaria* (Loosanoff, 1937b), and in some instances they gradually became filled with vacuolated cells.

During September, when the water temperature was at its maximum of about 15.0° C., and when partially and fully spawned clams were becoming progressively more numerous, ripe males, showing the so-called "packing" arrangement of the sperm, and ripe but unspawned females still were encountered. In October the temperature of the water was slowly declining but, nevertheless, spawning continued and during the first part of the month was, perhaps, even more active than in September. By the middle of the month the majority of the animals had completed spawning, and towards the end of the month the number of clams with spawn was rapidly diminishing (Tables I and II, Fig. 13).

FIGURE 10. Morphologically ripe gonad of a female during late December or in January. × 112.

FIGURE 11. Male gonad in late December or in January already containing ripe spermatozoa. × 475.

FIGURE 12. Eggs ready to be discharged in spawning showing dissolution of the germinal vesicle and the formation of chromosomal spindle. × 475.

During the last part of October and the early part of November the clams passed through the period of recovery consisting in part of resorption of unspawned material. However, as in *V. mercenaria,* there appeared to be no true indifferent period, when the follicles are free of all cells except the indifferent ones as is the case of *C. virginica* (Loosanoff, 1942; Coe, 1943). On the contrary, even then the sex of the clams was well defined, a condition which was especially clearly visible in the females because of the presence in their gonads of large numbers of ovogonia and young ovocytes. Sometimes such ovocytes began to develop before the old ones were discharged (Fig. 8). The presence in the follicles of well defined sex cells during all periods of the annual gonadal cycle indicated, of course, that sex in adult *C. islandica* is quite stable and that sex reversal, as was recently shown for *V. mercenaria* (Loosanoff and Miller, 1950), rarely, if ever, occurs.

After passing through the period of resorption of unspawned material, the clams enter a period of extremely rapid gametogenic activities which continues into December, regardless of the rapidly declining temperature. Some females possessed follicles containing either well grown ovocytes (Fig. 9) or ovocytes that were already so developed that they appeared morphologically ripe (Fig. 10). In males also all stages of development, from relatively unripe males in early stages of spermatogenesis to those the follicles of which contained many spermatozoa, were found (Fig. 11). If some of the material was taken from the spermaries of such advanced males and placed in sea water, the spermatozoa would soon begin swimming in their typical circular motion, indicating the ripeness of the gonads.

During the middle of winter, when the temperature is at its lowest, sometimes approaching only 1.5° C., gametogenesis was slowed down but probably not entirely arrested. Even at such a low temperature the clams remain somewhat active because in a laboratory experiment, in which they were placed in water of about 1.0° C., the clams opened the shells, extended their siphons, and pumped water, thus indicating that they were not hibernating.

With a gradual increase of the temperature in the spring, gametogenesis became progressively more rapid and eventually, by the end of June or early July, a state of physiological and morphological ripeness was achieved by individual clams.

Although the observations on the seasonal gonadal changes of the clams were carried on throughout the entire year, only those data obtained between March 15 and November 1 were analyzed statistically. The late fall and winter conditions were not included in the quantitative analysis. During that period, as already pointed out in the histological discussion, the gonads went through the recovery stage followed by rapid gametogenesis as the result of which approximately 20 per cent of the clams appeared to be morphologically ripe by about March 15.

For the quantitative studies the data were grouped in intervals of two weeks, accepting the mid-point of each of these intervals as the date for all the observations of that group. There were seventeen such intervals but in three of them observations were lacking (Table I).

All clams were assigned to one of four stages depending upon gonad condition. Stage A contained clams which were generally unripe but which, nevertheless, contained some ripe cells. The clams of Stage B were ripe, at least morphologically, but had not begun to spawn. Stage C consisted of partly spawned clams, while Stage D contained those that were completely spawned.

The observed frequencies of the clams in each of the four stages are presented in Table I. Inspection showed that the percentage of clams which have entered Stages B, C or D increases as the season progresses (Table II, Fig. 13). The analysis was based on the provisional assumption that the relation underlying this increasing percentage is the cumulative normal curve, the curves for the different stages of maturity differing only in the dates of their succession. In general, Figure 13 is a comparison between the cumulative percentages obtained from Table II and the theoretical cumulative normal curves which have been postulated.

Since it was found that approximately 20 per cent of the clams possessed gonads that appeared to be morphologically ripe by March 15, the lower limit of the percentage of clams that had entered Stage B at that date was not equal to zero but to about 20 per cent. Our hypothesis was extended to allow for this percentage, only assuming the normal cumulative curve of ripening for the remaining 80 per cent of the population. Accordingly, the number of clams closest to 20 per cent of the total sample in each group was subtracted from Stage B and from the total, giving the values of adjusted percentage in Stages B + C + D (Table II). No adjustment was made in the analysis of Stages C + D and D.

The cumulative percentages given in Table II, adjusted in the case of the class B + C + D, were used to estimate the approximate dates when 50 per cent of the clam population would be expected to have entered Stages B, C or D. Analysis showed that these dates probably fall within ± 3 days of June 15, August 13 and October 6 respectively. Thus, the time interval between the date when 50 per cent of the clams are expected to enter Stage B (ripe but unspawned) and Stage C (partly spawned) was 59 days, and between Stage C and Stage D (completely spawned), 54 days. It should be emphasized once more, however, that the mean date of June 15 applies only to the ripening of 50 per cent of those clams that were not morphologically ripe by March 15. As is evident in Figure 13, the mean date for the population as a whole is about June 4.

The same analysis showed a population standard deviation of 29 days. This means, for example, that 95 per cent of the population would enter a given stage during a period extending from about 60 days before to 60 days after the mean date.

As mentioned above, the standard error of the three critical dates was estimated to be ± 3 days. Larger samples of clams should provide greater precision of these estimates, but at present such refinement does not seem necessary. It was also possible to estimate the goodness of fit of the cumulative normal model, making a separate test of the assumption of equal standard deviations for the three stages of development. After a maximum likelihood fitting by the methods of probit analysis the residual $\chi^2 = 8.68$. We have allowed 28 degrees of freedom in the original 4×14 table, disregarding those classes with an expected frequency of less than one clam. In fitting the curves given in Figure 13, 18 constants have been used: 14 sample sizes, 3 means and the standard deviation. This leaves 10 degrees of freedom for χ^2, showing a satisfactory agreement. If individual slopes are fitted for the three cumulative curves, the sum of the 3 residual χ^2's $= 6.77$ with 8 degrees of freedom. The difference, $\chi^2 = 1.91$ with two degrees of freedom, arises from lack of parallelness of the three lines, and is not significant.

Our attempts to induce spawning in ripe *C. islandica* always failed. Methods, such as rapid increase in temperature, addition of suspension of sex products, changes of pH, salinity, etc., produced no results. During the spawning experiments it was found that the clams do not tolerate well temperatures over 27.0° and that at temperatures of 30.0° C. or higher they looked as if anesthetized, a condition manifested by relaxation of the adductor muscles and by expansion of the foot. Usually, subjection to such a high temperature was followed within a few days by a heavy, usually complete, mortality.

Natural unprovoked spawning was observed in only two cases. Once it occurred in the middle of winter, on February 3, 1945, when a single female kept in an aquarium in a cold room, the temperature of which was increased by direct sun to only 9.0° C., discharged a large number of eggs. The actual act of spawning was not seen but the eggs were found in a mass lying next to the clam. The eggs ranged from approximately 80 to 95 μ in diameter.

The second spawning occurred on July 19, 1948 when clams of both sexes, used several days prior to that date in an unsuccessful spawning experiment, spawned during the night. The temperature at the time of spawning was 22.0° C. The size of the eggs varied between 85 and 90 μ. Some of the eggs were fertilized and showed normal early development.

Attempts to fertilize artificially the eggs stripped from ripe females always failed because such eggs, even after being placed in sea water, still retained intact their germinal vesicles. Under normal conditions the germinal vesicle dissolves while the egg is still in the gonads of the mother clam, just before being discharged in the process of spawning. Immediately upon dissolution of the germinal vesicle a chromosomal spindle is formed (Fig. 12). After that the egg is ready for fertilization. In the stripped eggs, however, such changes do not occur and, therefore, fertilization is impossible. In this way *C. islandica* again closely resembles *V. mercenaria* in which artificial fertilization also cannot be achieved.

In preparing this article I feel especially obliged to my colleague, David W. Calhoun, for his statistical analysis of the data. I also wish to extend my sincere thanks to Charles A. Nomejko for the preparation of the photomicrographs and to William Arcisz for collecting and shipping to me many samples of clam gonads on which this article is based.

SUMMARY

1. The main period of gametogenesis in both sexes of *Cyprina islandica* occurs in late fall and early winter. In December or January the gonads of some clams present a morphologically ripe appearance, such individuals constituting approximately 20 per cent by March 15. Gametogenesis is slowed down but not entirely arrested during late winter and is resumed at a rapid rate with the spring increase in temperature.

2. Spawning begins near the end of June or early in July when the water temperature is approximately 13.5° C.

3. The dates when 50 per cent of the clam population should be expected to enter the stage of being ripe but not having begun to spawn, the stage of partial spawning, and the stage of completed spawning should fall within ± 3 days of June 4, August 13 and October 6 respectively.

4. In adult *C. islandica* the sexes are separate and well defined even immediately after spawning, thus indicating that sex reversal is uncommon.

5. The eggs of *C. islandica* cannot be artificially fertilized.

LITERATURE CITED

Arcisz, W., and L. A. Sandholzer, 1947. A technological study of the ocean quahog fishery. *Com. Fish. Review,* **9**: 1–21.

Coe, W. R., 1943. Development of the primary gonads and differentiation of sexuality in *Teredo navalis* and other pelecypod mollusks. *Biol. Bull.,* **84**: 178–186.

Coe, W. R., and Harry J. Turner, Jr., 1938. Development of the gonads and gametes in the soft-shell clam (*Mya arenaria*). *J. Morph.,* **62**: 91–111.

Jørgensen, C. B., 1946. Reproduction and larval development of Danish marine bottom invertebrates. 9. Lamellibranchia. *Medd. Komm. Danmarks Fisk. Havunders., Ser. Plankton,* **4**: 277–311.

Loosanoff, V. L., 1937a. Spermatogenesis in the hard-shell clam (*Venus mercenaria* Linnaeus). *Yale J. Biol. Med.,* **9**: 437–442.

Loosanoff, V. L., 1937b. Seasonal gonadal changes of adult clams, *Venus mercenaria* (L.). *Biol. Bull.,* **72**: 406–416.

Loosanoff, V. L., 1942. Seasonal gonadal changes in adult oysters, *O. virginica,* of Long Island Sound. *Biol. Bull.,* **82**: 195–206.

Loosanoff, V. L., and W. S. Miller, 1950. On sex reversal in adult clams, *Venus mercenaria. Anat. Rec.,* **108**: 131–132.

Merriman, Daniel, and Herbert E. Warfel, 1948. Studies on the marine resources of southern New England. *Bull. Bingham Oceanogr. Coll.,* **11**: 131–164.

Nelson, T. C., 1928a. Relation of spawning of the oyster to temperature. *Ecology,* **9**: 145–154.

Nelson, T. C., 1928b. On the distribution of critical temperatures for spawning and for ciliary activity in bivalve molluscs. *Science,* **67**: 220–221.

Rhode Island Department of Agriculture and Conservation, Division of Fish and Game, 1945. The ocean quahog fishery of Rhode Island. Pp. 1–31.

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Pages 586–587

127. BEHAVIOR OF CLAM LARVAE IN DIFFERENT CONCENTRATIONS OF FOOD ORGANISMS.

Victor L. Loosanoff, Harry C. Davis and Paul E. Chanley, U. S. Fish and Wildlife Service, Milford, Connecticut.

Larvae of *Venus mercenaria* were given different concentrations of food organisms ranging from 6,500 to 1,000,000 cells per cc. of water. The foods were a pure culture of *Chlorella sp.*, with cells averaging 8 μ in diameter, and a mixed culture consisting largely of small Chlorella cells averaging about 3 μ. The optimum concentrations, as indicated by the rate of growth and survival of larvae, depended upon the size of the cells. With large cells the optimum concentrations were near 50,000 cells per cc., while 400,000 to 500,000 cells per cc. of the smaller forms were needed to maintain the same rate of growth.

Heavy concentrations of food cells killed the larvae. These concentrations depended again upon the size of cells. A concentration of 350,000 cells per cc. of large Chlorella killed the larvae within a few days and 750,000 cells, sometimes within 24 hours. When fed the smaller cells the larvae grew well in concentrations of 750,000 cells per cc.

The filtrate, the cells, or a combination of the two, may cause death of the larvae if present in large quantities.

The larvae showed both quantitative and qualitative selectivity in feeding. In heavier than optimum concentrations of cells, many larvae contained less food in their stomachs than the larvae in lighter food concentrations. This indicated that larvae are not merely mechanical feeders but possess a mechanism for controlling the food intake. If kept in a heavy concentration for a long time, the regulating mechanism was lost and the larvae became choked with food cells. If not too seriously injured, such larvae, when removed to sea water containing a near optimum concentration of food, expelled the excess food and continued to develop normally.

Qualitative selectivity of food was demonstrated when the larvae were fed a mixture of several food organisms; given a mixture of Porphyridium (3 μ) and Chlamydomonas (10 μ) the larvae rejected Porphyridium while ingesting the much larger Chlamydomonas.

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247. EFFECT OF OVERCROWDING ON RATE OF GROWTH OF CLAM LARVAE. Victor L. Loosanoff, Harry C. Davis and Paul E. Chanley, U. S. Fish and Wildlife Service, Milford, Connecticut.

The rate of growth and survival of clam larvae *(Venus mercenaria)* was determined in (a) cultures maintained at different population densities but receiving the same concentration of food, and (b) cultures where the increase in the larval population was accompanied by a proportional increase in the food given.

In the first series the larval populations varied in the different cultures from 6.5 to 50 larvae per cc., but all cultures received daily 100,000 cells per cc. of a unialgal culture of *Chlorella sp.*

The larvae in all cultures grew to metamorphosis but the rate of growth of the different cultures had an inverse relation to the population density. At ten days the mean length of the larvae in the series of cultures containing 6.5, 12.5, 25 or 50 individuals per cc. was 162, 156, 151 or 144 μ respectively. The slower growth in the more crowded cultures may be attributed in part to more frequent collisons between the larvae, and in part to the deleterious effects of the greater concentrations of the excretory products of the larvae themselves.

In the second series the number of Chlorella cells was increased in proportion to the increase in the larval population. The cultures contained 6.5, 12.5, 25 and 50 larvae per cc. and received 100,000, 200,000, 400,000, and 800,000 Chlorella cells per cc. per day respectively. At ten days the average lengths of larvae in the cultures were 162 μ for the least crowded culture and 148 μ in the second lightest concentration of larvae. Those that received 400,000 Chlorella cells per cc. died within four days and those receiving 800,000 cells per cc. died within 48 hours. As far as rate of growth is concerned, an increase in food proportional to the increase in the number of larvae will not always compensate for the increase in larval concentration.

PIONEER LONGLINING
FOR TUNA ALONG THE EQUATOR

By

DONALD L. McKERNAN
Assistant Director
Pacific Oceanic Fishery Investigations

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July, 1953

PIONEER LONGLINING For Tuna Along the Equator

By DONALD L. McKERNAN
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The fishing trip of the west coast purse seine vessel, *Cavalieri,* in equatorial waters of the central Pacific during the past summer (June-September 1952), was a logical development from two years of study of the tuna resources of this vast region by the Pacific Oceanic Fishery Investigations. The vessel fished for a total of 33 days and landed a catch of 48 tons of tuna and 4½ tons of marlin and shark. The tuna was sold in San Pedro, Calif., while the marlin and shark were sold in Honolulu to a fish cake (kamaboko) plant.

This cruise was of special interest in two respects: (1) It was the first attempt by an American fishing boat to fish the waters of the central Pacific hundreds of miles from land in the "tuna rich" zone near the Equator, and (2) it was the first attempt by a west coast vessel to fish commercially with the Japanese longline gear.

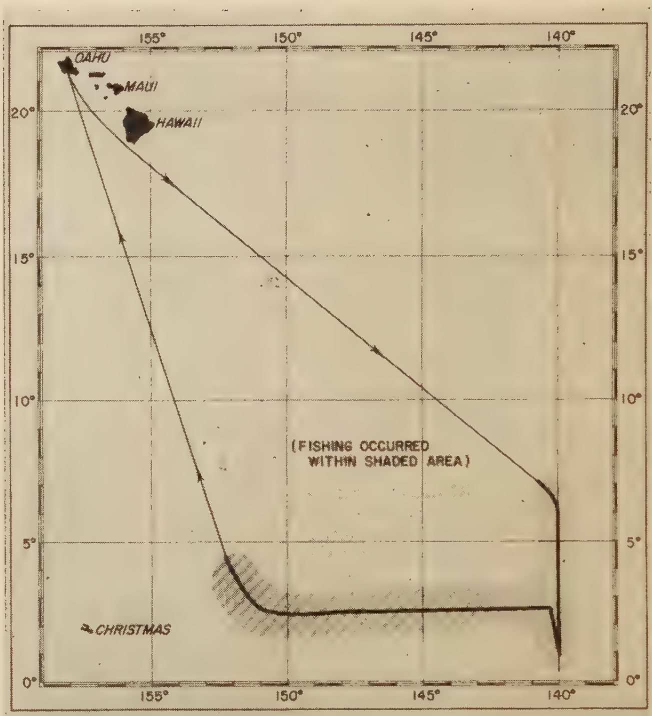

FIG. I EQUATORIAL REGION FISHED BY THE CAVALIERI AUGUST 21 TO SEPTEMBER 20, 1952

The *Cavalieri* voyage was planned to test the feasibility of commercial longline fishing in the unexplored region along the Equator on the 140° W. meridian, a distance about 1,500 miles from Honolulu and 2,100 miles from San Diego (Figure 1), and to study the distribution of tunas along the Equator in the eastern portion of the Pacific. The voyage was a joint venture by the owners of the *Cavalieri* and the United States Fish and Wildlife Service. The catch was sold on the open market with crew and owner sharing in the receipts. The government participated on the basis of a charter fee. The contract entered into by the *Cavalieri* owners and the government, among other things, stipulated the fishing of ten test stations across the rich zone at a specified location along the Equator. It also provided for two scientific observers from POFI to accompany the vessel.

A P.O.F.I. scientific worker aboard the "Cavalieri" taking measurements of landed tuna. Note the exceptionally large size of these specimens, which are fairly representative of the type of fish taken by longlining.

Fishing survey records compiled by POFI during 1950 and 1951 indicated the existence of a rich band of tuna along the Equator, 300 to 400 miles wide and extending from 180° longitude in the west to 150° W. longitude in the east. The *Cavalieri's* trip was intended to extend our knowledge still further east to 140° W. longitude, and closer to the American mainland.

The *Cavalieri* sailed from San Francisco to Honolulu and after pro-

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visioning and minor repairs proceeded to the fishing grounds at the Equator, arriving at the first station (6° N., 139° 41.5′W.) on June 21. After fishing for two days an engine breakdown forced the return of the *Cavalieri* to Honolulu. During those two days fishing was excellent, but because the vessel was experiencing mechanical difficulties, only 50 baskets of longline gear (300 hooks) were set each day. (Table 1). The 2½-ton catch of tuna was sold in Hawaii when the vessel returned for repairs.

After repairs were made the *Cavalieri* on August 21 returned to the fishing grounds and fished the remaining 8 test stations. Figure 2 and Table 1 show that the region of best fishing as determined from these 8 test stations was between 1° 20′ and 3° 30′N.

After the test stations were completed, the vessel returned to the latitudes of best catch, but the heavy concentrations of fish were not found immediately, and mediocre fishing continued for about 9 days along 140° W; the vessel then headed west, fishing during each day and running during the night. Fishing remained under 1.5 tons per day until reaching 149° 18′ W. and 1° 17′N. (station 24) when the catch rose to about 2 tons for the day. Thereafter, with the exception of station 27, the daily catches were better, and the *Cavalieri* averaged 2 tons of marketable tuna per day.

For the 23-day period of commercial endeavor (Table 1) 34 tons were taken for an average of 1.6 tons per day of marketable tuna. Including the catch from the first 8 test stations, 45.6 tons of tuna were sold to the cannery, in addition to 4½ tons of marlin and shark sold in Hawaii to a fish cake (kamaboko) plant.

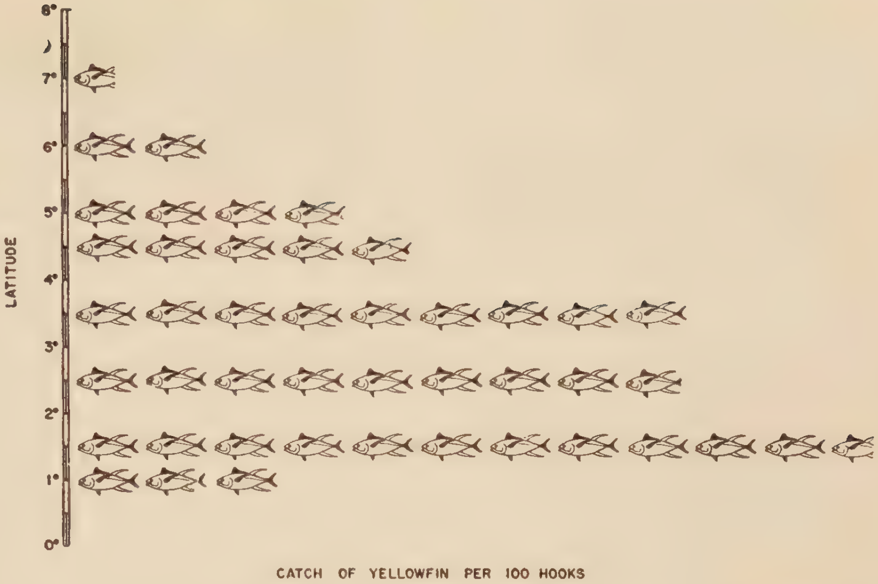

FIG. 2 THE CATCH RATE OF YELLOWFIN BY LATITUDE AS DETERMINED BY THE FIRST EIGHT TEST STATIONS. AUG. 21 - 28, 1952

The *Cavalieri* averaged 5.2 yellowfin per 100 hooks during the 23-day period of commercial fishing. The Japanese fishing longline gear in the western Pacific average about 2.4 yellowfin per 100 hooks and consider that rate of capture commercially economical. Thus the *Cavalieri* rate of capture is 2.2 times better than experienced in the western Pacific.

Considering the long hours customary in many commercial fisheries the effort expended by the crew of the *Cavalieri* was not excessive. It took 1.8 hours to set the average 78 baskets of gear and 5.7 hours to haul it. Usually hauling the gear began about 11:30 a.m. and ended at 5:00 p.m. Some additional time was usually spent each morning mending gear and untangling lines. Even so I believe more gear could have been set, possibly as much as 100 baskets, without undue hardship to the fishermen. Since this still would not be profitable the commercial adoption of this method of fishing involves improving the gear and method of handling so that instead of 480 hooks (80 baskets) a minimum of 900 hooks could be fished each day.

The catch along 140° W. longitude was composed of very large yellowfin averaging about 150 pounds. The fish caught later in the voyage at 145° W. averaged about 140 pounds in weight, while the 177 yellowfin taken along 150° longitude further to the west averaged only 125 pounds. This gradation of sizes from larger fish in the east to smaller as one goes west has now formed a consistent pattern as can be seen by the summary of the sizes of yellowfin captured by longline gear along the Equator (Table 2). The average size decreases from 148 pounds at 140° W. longitude to 62 in the far western Pacific. (The data from west of 180° was collected from Japanese mothership operations.) There is a belt lying south of Hawaii and stretching 1,800 miles from 150° to 180° W. longitude where the average is about 110 pounds and only a small percentage of the catch is over 150 pounds.

Table 2. The average size of yellowfin tuna from the western to eastern equatorial Pacific

Longitude	Number of tuna sampled	Average weight in pounds	Percent above 150 lbs.
135° E	195	62	0
(Mandate Islands area)			
145° E	627	78	0
155° E	3,077	84	0
180°	44	108	0
170° W	61	115	6
160° W	72	113	4
155° W	208	115	4
150° W	247	118	9
140° W	349	148	50
130° W	52	142	42
120° W	52	131	37
(Due south of San Diego)			

Hauling long-line tuna gear aboard the "Cavalieri." Note the Japanese-type gurdy used. The man at the right is coiling a "dropper" line, the long gangion from which a hook is suspended.

Table 1. A summary of longline fishing on the *Cavalieri*.

Date 1952	Set	Baskets	Numbers of fish caught[1]					Latitude[2]	Longitude	Catch/100 hooks YF[3]
			Yellow-fin	Big-eye	Skip-jack	Marlin	Shark			
			Part 1 - June 21 - 22, 1952							
6/21	1	50	16(4)	10(5)	1	-	4	06°00'N	139°41.5'W	5.3
6/22	2	50	26(7)	1	-	-	1	05°19'N	139°34'W	8.7
			Part 2 - August 21 to September 20, 1952							
			Test Stations							
8/21	1	50	2	1(1)	-	2 Bl.	1	07°07'N	140°47.6'W	0.67
8/22	2	50	4(1)	1	-	2 Bl.	11	05°58'N	140°30'W	1.7
8/23	3	60	15(3)	4	-	-	8	05°14'N	140°14'W	4.2
8/24	4	60	18(1)	-	4(1)	-	3	04°23'N	139°38'W	5.0
8/25	5	60	34	7	2	-	8	03°26'N	139°56'W	9.4
8/26	6	61	32(6)	-	-	-	4	02°23'N	140°02.5'W	8.9
8/27	7	70	49(11)	-	1(1)	-	12	01°32'N	139°55'W	11.7
8/28	8	70	12	-	1	1 Wh.	6	00°59'N	140°07'W	2.9
			Commercial Fishing							
8/29	9	70	24(3)	-	1	-	6	02°05'N	140°22'W	5.7
8/30	10	70	25(4)	1	1	1 Str.	7	03°37'N	140°15'W	6.2
8/31	11	76	34(7)	-	-	1 Str.	12	03°39'N	140°15'W	7.7
9/1	12	70	14(1)	-	1	-	6	03°31'N	140°12.5'W	3.1
9/2	13	79	19(2)	-	4(1)	-	5	03°04.5'N	139°52'W	4.2
9/3	14	79	8(3)	-	-	-	14	04°02'N	139°57'W	1.6
9/4	15	60	12	1	-	-	3	03°15.5'N	139°58'W	3.3
9/5	16	75	22	4	2	-	-	02°24'N	140°12'W	4.9
9/6	17	79	23(1)	3(1)	1	-	4	02°11'N	140°32'W	4.8
9/7	18	80	18	3	-	1 Wh.	6	01°51'N	141°49.5'W	3.8
9/8	19	80	22(3)	4	-	-	4	02°25'N	142°04'W	4.6
9/9	20	80	21(4)	1	-	-	7	02°30.5'N	142°57'W	4.4
9/10	21	80	15(3)	1	5	-	1	02°12'N	144°59'W	3.1
9/11	22	80	20(3)	-	-	1 Bl.	5	02°45'N	147°05.5'W	4.2
9/12	23	80	9	4	-	1 Bl.	10	02°25'N	148°47'W	1.9
9/13	24	80	27(5)	4(2)	1	2 Bl.	8	01°17'N	149°18'W	5.6
9/14	25	81	27(9)	2(1)	2	-	9	01°34'N	149°47.5'W	5.5
9/15	26	80	24(3)	2(1)	-	2 Bl.	3	01°57.5'N	150°02'W	5.0
9/16	27	85	15(5)	2	-	2 Bl.	1	02°23.5'N	150°17'W	2.9
9/17	28	80	33(9)	3	-	1 Bl.	2	03°19'N	151°24'W	6.8
9/18	29	80	61(26)	6	3	1 Bl.	8	03°37'N	151°36'W	12.6
9/19	30	80	43(9)	6(2)	-	-	4	03°44.5'N	151°54.5'W	9.0
9/20	31	80	38(6)	5(2)	-	-	12	04°04'N	152°10.5'W	7.9

1/ Figures in parentheses are shark-damaged; they are included in adjacent daily total.

2/ Positions when gear was set.

3/ Includes shark-damaged fish which were not suitable for sale. These amount to about 10% of the catch.

The *Cavalieri* was reputed to carry between 80 and 90 tons of tuna in her brine wells, but very early in the trip it became obvious that a capacity load of these large fish would be less than 60 tons. On September 20 the last brine tank was filled and the vessel was forced to return to Honolulu with 50 tons of fish. The marlin and shark were dry frozen in the small dry storage space which could have held about 4 tons more of dry frozen fish. In addition bait, fuel, and food were running low so fishing ceased when the last brine tank was filled. The vessel had fished a total of 31 consecutive days on this, the second part of the trip. This freedom of interruption by weather is characteristic of equatorial longlining.

The fish were unloaded at French Sardine Co. in San Pedro, and through the excellent cooperation of the officails of this company, accurate records were kept of the fish catch as it was unloaded and canned. Of the 91,255 pounds of yellowfin and bigeye delivered to the cannery, 27,750 pounds were rejected. The rejections were from the bigeye of all sizes and from the large yellowfin. The load included 10,000 pounds of bigeye tuna, of which some 85 percent, or about 8,500 pounds, were rejected. Of the yellowfin about 19,000 pounds were rejected. A breakdown of the yellowfin rejections by size categories is given in Table 3.

Table 3. Cannery rejection of yellowfin and bigeyed tuna.

Species	Size	Percent rejected by number
YF	Small—80 lbs. and under	0
YF	Medium—81 to 125 lbs.	6
YF	Large—126 to 150 lbs.	14
YF	Extra Large—151 lbs. up	70
BE	Less than 150 lbs.	85
BE	Over 150 lbs.	85

From this table it is plain that the moderate-sized yellowfin from the equatorial region of the central Pacific were acceptable for canning, only 6 percent of the fish weighing less than 125 pounds being rejected; between 125 and 150 pounds the rejections were 16 percent. However, the large yellowfin were off color and observations at the cannery substantiated earlier findings that the majority of fish above 150 pounds (70 percent in the case of the *Cavalieri*) were most likely to be rejected primarily because of the generally darker flesh color.

Samples of tuna of various sizes were canned for later examination. Observations on these showed the flesh of the Yellowfin above 150 pounds to be usually noticeably darker in color and in many instances to be too dark for labelling "light meat" tuna. In most cases the flavor of these larger fish was equal to that of the smaller.

DISCUSSION

Reviewing the *Cavalieri's* experience we learn that:

1. West Coast fishing vessels of the *Cavalieri* type are readily adaptable to longlining.
2. Weather interruptions need not be feared.
3. There must be an improvement of gear and the method of setting so that much more gear can be operated daily.
4. Storage of fish is a problem. Possibly some trimming would be effective. Removal of the long, stuff fins, the tail and possibly the head should allow more compact stowage.
5. Localities where the larger sizes (over 150 lbs.) of yellowfin and bigeye tuna are abundant should and probably can be avoided since the majority of yellowfin over 150 pounds and most of the bigeye were rejected by the cannery.
6. The catching rate in the tuna rich zone continued to prove out better than the adjacent water to the north and south, and was about twice as good as the average for Japanese fishing west of 180° longitude. On the other hand it was poorer (5.2 per hundred hooks) than the prior general average for POFI's surveys (6.3 per hundred hooks).
7. The *Cavalieri* had consecutive days of generally poor catches and consecutive days of very much better catches. This element in her experience suggests the value of further research of the kind that would eventually lead to setting gear in the best localities. If this knowledge could be attained, a doubling or trebling of the already superior average catching rates would follow.

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COMMITTEE ON HYDROBIOLOGY AND FISH CULTURE

JAMES W. MOFFETT

The fact that this committee was asked to prepare a report on research needs in fisheries, that the Wildlife Society has prepared a similar report for its field, and that many articles on the needs for research in other areas have appeared recently in several journals, is highly indicative of a widespread feeling of a basic weakness in the sciences. This atmosphere of unrest is certainly a mark of "growing pains" in scientific circles in America. Here is an indication of incipient maturity—a desire to move from the technological and developmental phase in American science to a more contemplative, deliberative stage. These signs are gratifying and offer a hope that production of new principles, new ideas, theories, and systems may become a more prominent attribute of American science.

IMPEDIMENTS TO EFFECTIVE RESEARCH

To a large degree the impediments to effective research have their roots in our very culture—a culture that confuses scientific engineering with true research, that deifies technological "know-how" but has little patience for the drab, tedious, long-term inquiries on which it is based. Horowitz [1] has described the present status of our culture so aptly that some of his remarks are quoted herewith:

> "We live in an atmosphere and within a system that value the football coach more than the scholar. . . . We lay more stress on doing, on importance of the *act,* and less on knowing. . . . We glory in our "know-how", in our mechanical ability, in overt accomplishment. And whether for good or evil, our educational institutions are turning out people, who, by training, *fit into* this cultural scheme. . . . Our theorists, thinkers and system builders are, for the most part, second-rate. . . . We place great value on memory, on facts, on knowledge for a purpose. And always with us is the emphasis on grades. We tend to stimulate learning not through intrinsic interest or desire for knowledge but through an external and irrelevant incentive. Try as I will, the image of the donkey with the carrot held just out of reach of it continually comes to mind.
>
> "The rigidity of the classroom, the compulsory attendance, the required courses, the omnipresent quiz and examination, all combine to stifle spontaneity and creativity and to drive the student along a prescribed path that someone else considers desirable. It is no etymological accident that students frequently refer to their college as the factory, for in many respects our educational system is of the assembly-line, canned variety."

If Horowitz' description of our research "climate" is correct, it appears difficult to find a place in fisheries for research in the sense of the following dictionary definition: "Studious inquiry or examination; specifically, and usually, critical and exhaustive investigation or experimentation having for its aim the discovery of new facts and their correct interpretation, the revision of accepted conclusions, theories, or laws, in the light of newly

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[1] Horowitz M. W., 1952, Teaching, research and thinking. The Scientific Monthly, Vol. 74, pp. 332-337.

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discovered facts, or the practical applications of such new or revised conclusions, etc.".

The difficulty in finding a place for research in fisheries lies in the attitudes of many groups—the general public, anglers, commercial fishermen, administrators, legislators, and fishery biologists themselves. These attitudes run the full gamut from frank disinterest to an overabiding faith in the wonders of science—faith that turns sour when the anticipated miracles do not come off. All of these groups share, even though to a varying degree, an impatience that can be satisfied only by immediate and categorial answers; all are intolerant of any long-term or "impractical" research; all must have action even though it be nothing more than a frantic and futile scurrying about. Let us now examine a little more closely this question of attitudes; through the examination we may find the way to escape from some of our difficulties.

The general public concept that scientists are magicians to whom nothing is impossible is especially influential in the establishment of research programs in fisheries. Many persons, including some fishery administrators, believe or have believed that all troubles in fisheries will disappear immediately when scientists are added to the staff. With this naïve faith, it is understandable that their enthusiasm should be transformed to resentment when the administrative miseries persist; that research as an activity should come into bad odor and scientists be regarded as impractical and curious "fiddlers" undeserving of support; that investigational programs should so often be rendered impotent by lack of support. Surely we need improved understanding by administrators of the true nature of research and by researchers of the urgency of administrative problems.

The administrator for his part should realize that no basis exists at all for the classification of research as "practical" or "academic". All research that contributes to our knowledge of the way fish live is practical; properly conducted inquiries, on the other hand, are academically sound whether or not they are designed to yield immediately useful results. The administrator must grasp further that it is no more possible in fishery science than in agriculture to plant today and harvest tomorrow. When he makes unreasonable demands for quick appraisals of complex problem situations and comprehensive management programs for waters barely seen, much less studied, he is forcing charlatanism on his staff and inviting discredit on himself.

Scientists, in their turn, should recognize that the last word need not be said in an inquiry before some use can be made of the results. An investigation that has been properly planned and intelligently executed almost certainly will yield instructive results during its progress. An alert and cooperative researcher will inform himself as to the pressures that bedevil his administrative superiors and will regularly make available to them any findings that may contribute toward the easing of their problems.

In short, we need administrators who grasp that scientific facts cannot be ordered up like groceries in a market, that the results from a truly worthwhile research program can seldom be anticipated, much less stipulated and scheduled. We need just as badly scientists who can carry out basic inquiries and at the same time assist administrators in their problems without stooping to superficiality.

Another condition militating against research in fisheries arises from the tendency in some of our educational institutions to graduate persons as fishery experts and not as biologists. Furthermore, these persons are encouraged to do research even though they have received little training for the pursuit. Their training is for action rather than analysis. Yet a great many graduates want to do research in positions or in organizations not established or operated for the purposes. The result is a multiplication of disjointed, isolated efforts, generally misdirected, that yield very little except misunderstanding and ill-will toward research as an approach to fishery problems.

Actually, the research field in fisheries is overcrowded with persons busily engaged in data collecting, field work, and management plans. Analysis and mature consideration of materials and data never seem to receive the proper emphasis. Collections of data can, and very often do, become useless burdens if they are not subjected to the quiet, wholesome deliberation and logical analysis necessary to force them to yield the information they contain. Anyone can collect data. But the power of cold, unbiased analysis is possessed by few on our fishery research staffs, not because capabilities for such analysis are essentially inborn but rather because they are not taught, or better yet, instilled by contact and example.

In our general approach to a fishery problem we exhibit a passion for *doing*, for *physical activity* and a revulsion at the mental drudgery and physical inactivity that inevitably go with the analyses. As a result we accomplish little real research. All of us recall instances where support for a program was forthcoming as long as it was an *action* program. But as soon as deliberation and treatment of data required long hours of physical *inaction,* the data were left untouched, and the persons reassigned to another *action* program. The researcher had only his personal impressions to offer as the result of all the field work. These impressions were always qualified and nebulous. Under such circumstances, the administrator is forced to conclude that research is expensive, yields nothing but vague opinions and merits no further consideration as a part of his *action* program.

Without the experience of doing the mental tasks in research, whether it be in management or in the so-called basic investigations, few men will be capable as researchers; furthermore, many persons illadvisedly trained as or encouraged to become researchers will never qualify. Lindsay[2] recognized this fact in a similar discussion of research in the physical sciences: "Anyone who seriously believes that the insatiable curiosity about nature and the rigid mental self-discipline that are the characterizing marks of the scientist will ever manifest themselves in more than a negligible percentage of the population has little regard for the teachings of history."

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[2] Lindsay, R. B., 1952, The Survival of Physical Science, The Scientific Monthly, Vol. 74, pp. 139-144.

A researcher must be imbued with the spirit to adventure, the wit to question and the wisdom to accept and use.

Two additional evils operate against orderly progress in fishery research at the present time. One is the drain of trained, qualified and well established scientists from our colleges and universities into government-sponsored research projects. Obviously, this drain leaves something to be desired in our student-training programs. The other evil, which is gradually being eliminated, consists of requiring promising scientists to assume greater and greater burdens of administration as they progress up the pay scales of our various research institutions. Through this policy our best, most mature talent is lost to the very activity in which it showed aptitude. Administrative responsibility has smothered many scientific careers and dwarfed many programs by removing the very key men who had the attributes necessary for sound research. There is no profit in the policy which pays salaries according to relative position on the organizational chart and gives no proper compensation for talent and ability.

Recommendations for the Improvement of Research

In our comments on impediments to effective fishery research we have automatically emphasized some of the needs in the field. As we have explained, many of the troubles in fishery research transcend the field of fisheries and have their bases in our national character. Time and maturity will correct many present weaknesses but much can be done now to strengthen research efforts in the field of fisheries. It is difficult to make recommendations on fishery research without feeling that perhaps we cannot see the broad aspects because of the details. However, at the risk of being presumptive, we offer the following suggestions in the light of the preceding discussion:

1. Provide the proper "climate" for research; remove pressures wherever possible; pay adequate salaries; balance short- and long-term researches; insist on project completion; allow individual development and expression; do not frown upon, or consider a waste of time, literature surveys, reflection, and constructive dreaming (even the weirdest of ideas may produce surprisingly valuable results).

Of course research personnel need supervision and attention. Problems should be well defined and the programs to obtain their solutions well designed. Once the problem is assigned, provide the means to do the work—funds, labor, and facilities. Nothing is more discouraging to researchers than to receive an assignment of a problem with no provisions for conducting the investigation. Avoid frequent changes of programs and personnel, exorbitant assignment of work, unnecessary assignment of work outside the field of research, and "red tape", which all tend to lower the quality and quantity of the research.

2. Provide for free exchange of ideas and philosophies by eliminating restrictions placed on the recruitment of personnel—especially those requirements which make for provincialism and "home town" scientists. Encourage exchange of personnel between different geographical areas, travel to meetings, contacts, and conferences.

3. Provide adequate funds for research activities. Research budgets should not fluctuate widely and erratically. A dependable commitment through the years, one which will allow real planning and not require frantic, annual justification or result in alternate prosperity and poverty will yield more per dollar than any other method of financing. We must strive for high quality of work rather than for a large, showy program of poor or mediocre quality.

4. Provide for prompt and efficient media of publication.

5. Establish research centers, or institutes, supported by the states and the federal government, dedicated to the discovery of basic facts and principles, and free from the "service work" so characteristic of research units immediately subservient to administrative units.

6. Encourage fishery research in colleges and universities. Small or poorly financed fishery administrations can accomplish much for a very little by following this policy. Some of the best fishery research has been done by graduate students. Two purposes can be served for the price of one; problems are solved and men are trained.

Many universities are in an excellent position to carry on long-term investigations. The persons in charge of university research usually have long tenure, are research-minded, and in the use of student aid can so organize the project that the turnover of students does not detract from the progress. It is believed that too often universities are not aware of the major fishery problems that lend themselves to long-term research. States may cooperate to their own benefit with the universities in providing facilities, advising of problems, or in otherwise paving the way necessary for a sound long-term program.

7. Strive always to enlist the aid of specialists in other fields of science. A fishery biologist cannot be competent in every field. His research will be sounder and will yield more information if it is augmented by the contributions of chemists, biochemists, engineers, bacteriologists, physiologists, physicists, economists, and others. Because of the specialization of training given in an increasing number of universities as well as the need for specialists in research, it is believed that a somewhat new approach should be taken in recruiting fishery research staffs. Other fields, such as animal husbandry, have for some time employed, with phenomenal success, personnel equipped with specialized training in the basic sciences and with or without extensive training in the immediate field in question. Furthermore, personnel trained in other fields almost invariably bring in new ideas.

8. Promote educational programs which describe, interpret, and justify fishery research.

9. Develop better understanding between administrators and scientists through mutual effort to become acquainted with all sides of a problem.

10. Avoid impatience, intolerance for other views, and the urge to force action programs exclusively.

11. Encourage our training centers to stress quality of students rather than numbers.

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CONSTRUCTION DETAILS OF TUNA LONG-LINE GEAR USED BY PACIFIC OCEANIC FISHERY INVESTIGATIONS

By Edwin L. Niska*

INTRODUCTION

This is a description of the long-line gear used at present by the Pacific Oceanic Fishery Investigations (POFI) to capture tunas in the central Pacific. The basic design is that employed by Japanese and Hawaiian fishermen (June 1950, Shapiro 1950), modified for ease of operation and standardization of component parts. In the past POFI has used different types of long-line gear (Murphy and Shomura ms.), and we anticipate that the design will be further changed in the future. The gear described in this report is, however, a thoroughly tested and practical gear for catching tunas and marlins up to several hundred pounds in size.

The basic unit of gear is the "basket," so called because it was originally stored in a split bamboo basket. This unit consists of a main line with a supporting float line at one end, and bearing six branch lines, each with a single hook.

MATERIALS AND COSTS

The following list of materials contains all the items that are necessary to make up one basket of POFI long-line gear:

Item	Quantity	Cost
Seine twine, cotton, No. 261 thread, hard lay	23.4 lbs.	$23.00
Preservative--"Net Life" or copper napthenate	½ gallon	.60
"Sekiyama," prefabricated No. 8 thread, Irish Linen, 12 strands, 22 ft. long	6 each	13.50
Wire rope, leader, .066" dia., 1 x 7 rt. lay, galv. mild plow, 6 ft. long	6 each	.36
Hooks, No. 9/0 or 8/0 "Mustad flatted tuna"	6 each	1.08
Sleeves, copper, "Nicopress" No. 18-1-C for 1/16" cable	12 each	.40
Snap, with swivel, Kolstrand, No. 9 AK	7 each	2.45
Rubber tubing, 1/8" I.D., 3/8" O.D., 6" long	6 each	.45
Pole, bamboo, 14-16 ft. long, butt dia. 1¼-1½ inches	1 each	.70
Strap, "Band-It," stainless steel, 3/8" width	2 feet	.12
Buckle, "Band-It," stainless steel, 3/8"	4 each	.24
Bunting, flag, Indian Head cloth, 8" x 11½"	2 each	.24

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	Quantity	Cost
Rubber, air hose, 1-1/8" I.D., 5/16" wall, 14" section	1 each	.80
Tank, stainless steel, internal volume 2100 cu. inches (Army surplus)	1 each	4.75
Eye bolt, 3/8" stock 4½" long, galv.	1 each	.55
Bushing, 1/4" x 1/8" hex head, galv.	1 each	.34
Canvas skid	1 each	2.07
Manila line, 3/8" dia. med. lay	5 feet	.15
Cotton line, 1/4" dia. med. lay	14½ feet	.60
Wire rope thimbles, 3/8" galv.	1 each	.10
Misc. cotton thread, No. 6 cord, sail wax, sealing compound		.10
		$52.60

In addition, the following special tools are needed:

"Nicopress" tool No. 51-C-887	$20.00
"Band-It" tool for 3/8" strap stock	12.00
Die OS 1/8" - 27 NPT	3.00
Die ratchet	6.65
	$41.65

It should be pointed out that the prices quoted on the above list have been derived from government bid quotations as delivered in Honolulu and, because of fluctuations in market prices and shipping costs, are only estimates. The cost of $52.60 to make up one basket of long-line gear does not include the cost of labor. It requires about 10 man-hours to assemble one basket of gear.

PREPARATION OF THE LINES

Before cutting, each skein of line is straightened and stretched to remove the kinks. Seven main-line sections, each 180 feet long, are cut and a 12-inch eye splice is made on the ends of each length.

The six branch lines are cut in 60-foot lengths. A No. 9 AK snap is attached to one end by a 1½-inch eye splice through the swivel ring. The standing end is stoppered with a Matthew Walker knot (as shown in part D of figure 1) in order to facilitate making a compact, readily breakable sheetbend around the eye of the "sekiyama."

The "sekiyama" contains 12 strands of No. 8 linen twine wound with No. 6 cotton thread. It is 22 feet long and has a 3-inch eye on each end. The eyes are served with No. 6 cotton wrapping twine with a lock stitch at the base of each eye, the wrapping continuing 3 inches beyond this junction. The purpose of the "sekiyama" is to serve as an additional leader which is very strong, stiff enough to be non-kinking, and yet easy on the hands. A large fish on the hook can be worked and boated safely because the winding thread on the "sekiyama" forms a good gripping surface. The "sekiyama" also can be bent on the rail of the vessel, whereas ordinary line would soon wear out by abrasion.

Leaders are fashioned of 6-foot lengths of 1 x 7, .066-inch diameter, galvanized wire. A 3-inch loop in the end of the leader is fitted with a section of rubber tubing to reduce chafing on the "sekiyama," the loop itself being secured with a Nicopress sleeve. A flattened No. 9/0 tuna hook is attached to the leader by a 1-inch loop made with a Nicopress sleeve.

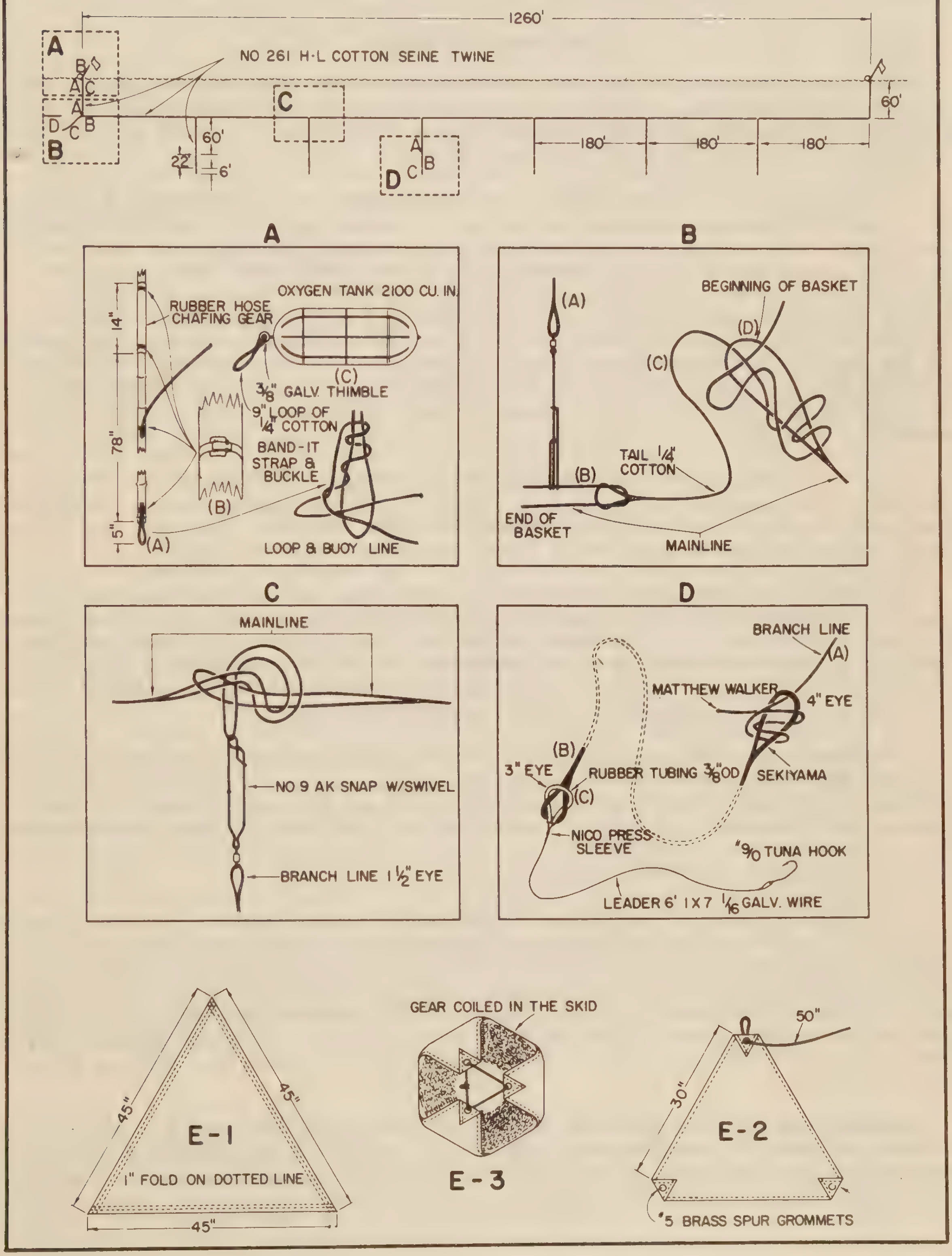

DIAGRAM OF POFI LONG-LINE GEAR

1260'
NO 261 H-L COTTON SEINE TWINE
A
B
C
D
60'
22'
6'
180'
180'
180'
A
RUBBER HOSE CHAFING GEAR
OXYGEN TANK 2100 CU. IN.
14"
78"
5"
(C)
3/8" GALV. THIMBLE
9" LOOP OF 1/4" COTTON
BAND-IT STRAP & BUCKLE
(B)
(A)
LOOP & BUOY LINE
B
(A)
BEGINNING OF BASKET
(D)
(C)
TAIL 1/4" COTTON
(B)
END OF BASKET
MAINLINE
C
MAINLINE
NO 9 AK SNAP W/SWIVEL
BRANCH LINE 1 1/2" EYE
D
BRANCH LINE
(A)
MATTHEW WALKER
4" EYE
(B)
3" EYE
RUBBER TUBING 3/8" OD
(C)
SEKIYAMA
NICO PRESS SLEEVE
#9/0 TUNA HOOK
LEADER 6' 1X7 1/16 GALV. WIRE
45"
45"
45"
E-1
1" FOLD ON DOTTED LINE
GEAR COILED IN THE SKID
E-3
50"
30"
E-2
#5 BRASS SPUR GROMMETS

A 60-foot buoy line is made up for each basket. This is secured to the main line loop at the end of the basket. The surface end is fastened to the base of the flag pole (see parts A and B of figure 1).

FLOATS AND FLAGPOLES

The most satisfactory buoy with long life and sufficient buoyancy is an Army surplus stainless-steel oxygen tank of 2100 cubic inches internal volume. It is 25 inches long, and $38\frac{1}{2}$ inches in circumference. There is a standard $\frac{1}{4}$-inch outlet fitting on each end (part A of figure 1).

The oxygen tanks are remodeled to serve as floats in the following manner: The outlet fittings are removed, and one end is sealed by a threaded $\frac{1}{4}$-inch galvanized plug. The opposite end is fitted with a 3/8-inch galvanized eye bolt with a 2-inch shank that has been threaded into a 1/4 x 1/8-inch hex head galvanized pipe bushing. As an additional waterproofing precaution, the plug and bushing threads are coated with Permatex sealing compound. An 8-inch grommet is formed from a length of 1/4-inch diameter cotton line. The grommet is first looped through the eye bolt, then secured to a 3/8-inch galvanized wire rope thimble, which prevents chafing of the cotton line by the eye bolt. This harnessing method makes the float easy to pull in when the gear is being retrieved and simple to detach for storage.

Poles with flags are attached to the buoys in order to facilitate locating the gear. The poles are select bamboo, 14 to 16 feet in length, with a butt diameter of $1\frac{1}{4}$ to $1\frac{1}{2}$ inches and a tip diameter of about 5/8 inch. They are cut 2 inches below the lowest joint and 3 inches beyond the uppermost joint.

The poles are protected from chafing on the float by a 15-inch section of air hose. This is slit lengthwise and pressed onto the pole with the lower end 6 feet 6 inches from the butt. It is secured by Band-It straps 1 inch from each end, with the buckles fixed over the cut. The attachment to the buoy is made so that the buckles are turned away from it presenting only the smooth band for chafing. The air hose is rather expensive, but can be used indefinitely.

A 5-inch loop of 1/4-inch cotton line is fastened at the bottom of the pole for attaching the float line. This loop is held in place as follows: A rosette is made in each end of the line and a "Band-It" strap is clamped midway on the rosette, which serves as a cushion preventing the loop from slipping under the band. The ridge at the lower joint of the pole tends to prevent the loop and band from slipping off the butt of the flagpole.

The float is tied to the flagpole by a 4-foot cotton lanyard of 1/4-inch cotton line, which is secured to the flagpole just below the chafing gear by a Band-It strap. It is important that this line be fixed 90 degrees from the concave side of the bamboo so that on lifting the pole from the water the weight of the tank will be borne by the bamboo in the direction of its greatest strength. This position is 180 degrees from the slit in the chafing hose. On setting the gear, the free end of the lanyard is joined to the grommet of the float by a reverse sheet bend with bow.

Bunting flags are attached to the top of the flagpoles by waxed doubled cotton thread ties fixed to the corners of the flags. Different combinations of colors are used to identify various portions of the set, such as the ends and center,

LONG-LINE CONTAINER

The original split bamboo basket which was formerly used to hold a "basket" of gear has been replaced by a canvas container or "skid" (part E of figure 1). This is made of No. 4 duck cut in the shape of an equilateral triangle, 45 inches on a side. It has a 1-inch table size seam that has been folded twice. The corners are turned in 3 inches with No. 5 grommets punched in the center. A 3/8-inch Manila becket 50 inches long is laced through the grommets. A 3-inch loop is spliced on one end, and the standing end is securely whipped. The loop is secured on one grommet by an overhand knot immediately behind the eye splice. The standing end is laced through the other two grommets and passed through the eye to form a bight. A slip knot is then made, thus securing the long-line within the confines of the canvas skid.

TREATING LINES WITH PRESERVATIVES

When in use the gear remains wet for weeks at a time and a preservative is necessary for all of the cotton parts. It is not necessary to treat the "sekiyamas." Among the several types of preservatives that have been used, "Net Life" and a copper napthenate compound have produced satisfactory results. The skeins of line are cold-dipped for a period of 15 to 20 minutes, after which they are removed from the preservative tank, allowed to drain, then placed on a rack to dry in the shade. Essentially, a preservative dip for long lines should be one that will penetrate the line and leave no gummy residue on the surface when dry.

ASSEMBLY OF LINES FOR SETTING

Prior to setting, the main lines and branch lines are joined as shown in part C of figure 1 and the gear is carefully coiled, branch lines alternating with sections of main line. The float line is attached to the main line and coiled on top of the basket. In setting, a float and the float line are attached to the flagpole. This assembly is then pitched overboard from the moving vessel, and the main line and baited branch lines are thrown out with plenty of slack. In the meantime the second basket is attached by joining the two main lines as shown in figure 1B. This is done with a 3-foot tail of 1/4-inch medium lay cotton line with a 3-inch eye splice in one end and the other whipped. The loop is attached to the main line of one basket and the free end is tied to the loop in the end of the main line of the next basket, another buoy and pole assembly is attached, and the setting process is repeated.

Hauling is done by means of a Japanese line hauler (Shapiro 1950, Shimada 1951). This has sheaves through which the main line is hauled and automatically coiled on a skid placed below the machine on a platform of suitable height. Float lines and branch lines are detached as they come on board. The buoys and flags are removed and stowed, and the float lines and droppers are coiled by hand. As the main line is coiled under the line hauler, float lines and droppers previously coiled by hand are attached in the proper places so that the "basket" is ready for use the following day.

DISCUSSION

Long-line gear is the best means at present known for catching deep-swimming tunas. It is uniform, easy to work, and readily constructed. The component main lines, branch lines, and buoy lines are all made from the same material. Uniform length of branch lines eliminates confusion in assembly and replacement during the pick-up. The fishing depth can be regulated as desired by altering the length of the buoy lines and the amount of sag in the main line. Tangling of adjacent branch lines is not frequent because the distance between any two branch lines is more than twice their length. The use of one large float between baskets, instead of two or more smaller floats, reduces the amount of handling and expedites operations. Snaps with swivels placed at the uppermost part of the branch lines minimize twisting when a hooked fish is threshing about. The snaps allow for instantaneous assembly or disassembly of the branch lines or buoy line with the main line. The manner of construction lends itself to mass production methods.

LITERATURE CITED

JUNE, FRED C.
1950. PRELIMINARY FISHERIES SURVEY OF THE HAWAIIAN-LINE ISLANDS AREA. PART I. THE HAWAIIAN LONG-LINE FISHERY. U. S. FISH AND WILDLIFE SERV. SEP. NO. 244, PP. 1-16.

MURPHY, G. I. AND SHOMURA, RICHARD
1952. LONG-LINE FISHING FOR DEEP-SWIMMING TUNAS IN THE CENTRAL PACIFIC, JULY 1950-SEPTEMBER 1951. MS.

SHAPIRO, SIDNEY
1950. THE JAPANESE LONG-LINE FISHERY FOR TUNAS. U. S. FISH AND WILDLIFE SERV. SEP. NO. 249, PP. 1-26.

SHIMADA, BELL M.
1951. JAPANESE TUNA-MOTHERSHIP OPERATIONS IN THE WESTERN EQUATORIAL PACIFIC OCEAN. U. S. FISH AND WILDLIFE SERV., COMMERCIAL FISHERIES REVIEW, VOL. 13, NO. 6 (JUNE 1951), PP. 1-26.

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STATUS OF NEW ENGLAND SEA-SCALLOP FISHERY[1]

By Ernest D. Premetz* and George W. Snow**

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FIGURE 1 - TWO SCALLOPERS--REDSTART AND CHRISTINA J.--TIED UP AT A NEW BEDFORD DOCK GETTING READY FOR ANOTHER TRIP.

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[1] PREPARED AT THE REQUEST OF THE ATLANTIC STATES MARINE FISHERIES COMMISSION.

NOTE: ONLY THE SEA SCALLOP'S LARGE MUSCLE THAT CONTROLS THE SHELL MOVEMENTS IS MARKETED. SCALLOPS ARE SHUCKED AND THE LARGE MUSCLES (CALLED "EYES") CUT OUT ABOARD THE VESSEL, BUT THE REMAINDER IS GENERALLY DISCARDED. THEREFORE, THE SCALLOP MEATS LANDED REPRESENT ONLY A SMALL PROPORTION OF THE GROSS OR NET WEIGHT OF THE SCALLOPS.

INTRODUCTION

The giant or sea scallop, Pecten grandis (Solander),[2] is today one of New England's major fishery resources. The past two decades have witnessed about a tenfold rise in production--almost 20 million pounds of scallop meats, valued in excess of 9 million dollars, were landed in the peak year of 1950.

FIGURE 2 - A CLOSE-UP VIEW OF A TYPICAL NEW BEDFORD SCALOP DRAGGER (MOONLIGHT) IN PORT.

The industry has in past years expressed concern for the future of the fishery. Although the over-all production trend has been upward, there has been a general belief among scallop fishermen that production was maintained at the expense of depletion of certain grounds and that the present rate of fishing would result in ultimate depletion of all areas. Fishermen have reported that in many areas they are forced to work longer to get a trip.

Recognizing the need for a more adequate knowledge of this fishery, the U. S. Fish and Wildlife Service in July 1943 instituted routine collection of data relative to the fishery at New Bedford, Mass., now the world's largest sea scallop port. Since that date, skippers of scallop draggers landing at the port of New Bedford have been interviewed by a representative of the Fish and Wildlife Service. The information obtained includes the sailing and landing date, grounds and depths fished, actual fishing time,[3] and quantity of scallop meats landed. From these basic data it is now possible to present a general picture of the activities of the scallop fleet as it has shifted from ground to ground and to obtain some information on the changing abundance of scallops in different areas during the past nine years.

Members of the scallop industry have asked that some regulation be applied to the fishery in order to insure maintenance of the high productivity which has characterized the operations over the past years. Before any recommendations for conservation measures can be made, two basic questions must be answered: (1) Are there signs of depletion on the scallop grounds? (2) How long can the grounds withstand present fishing intensity?

An answer to the first question can be given on the basis of the interview data collected over the past nine years. The second question cannot be fully answered until more is learned about the biology of the sea scallop.

UNITED STATES LANDINGS

In table 1 are tabulated the United States landings of sea scallops (meats only) by state and region for all years since 1889 for which records are available.

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[2] THE CORRECT SCIENTIFIC NAME OF THE SEA SCALLOP HAS BEEN THE SUBJECT OF CONSIDERABLE DEBATE. MODERN TAXONOMISTS SEEM TO AGREE ON PECTEN GRANDIS (SOLANDER). OTHER NAMES FOUND IN LITERATURE ARE P. MAGELLANICUS (GMELIN) AND P. TENUICOSTATUS (MIGHELS).

[3] "DAYS FISHED" AS USED IN THIS REPORT INCLUDES TIME SPENT IN ACTUAL FISHING AND MOVEMENT FROM GROUND TO GROUND, BUT DOES NOT INCLUDE TIME SPENT "JOGGING" DURING ADVERSE WEATHER.

There are only sporadic records from 1889 to 1929. From 1929 to the present the records are fairly complete. The variations in U. S. landings from 1929 through 1952 are shown graphically in figure 3.

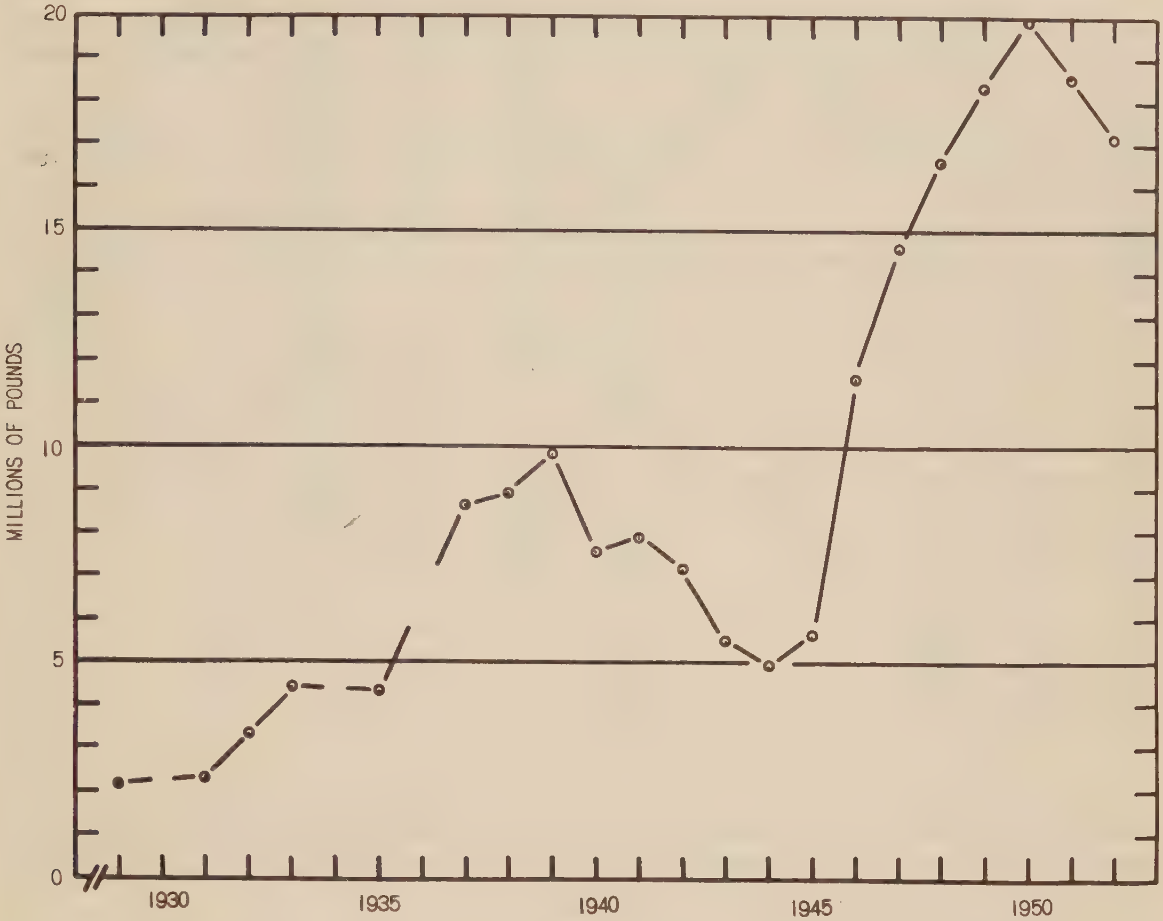

FIGURE 3 - TOTAL UNITED STATES LANDINGS OF SEA SCALLOPS (MEATS ONLY), 1929-52.

We note that landings rose from slightly over 2 million pounds of scallop meats in 1929 (the first year for which we have complete statistics) to almost 20 million pounds in 1950, reaching an initial peak of about 10 million pounds in 1939, dropping during World War II to slightly less than 5 million pounds in 1944, and then rising rapidly to the peak in 1950. Landings decreased in 1951, and in 1952 dropped to about 17 million pounds--the lowest since 1948.

COMPARISON BY REGIONS: In the early years of the fishery by far the greatest portion of the United States sea-scallop catch was landed in the New England States, but with the discovery of scallop beds off Long Island in the early 1920's, the Middle Atlantic ports assumed leadership. Many of the boats fishing the New England area (principally off the Maine coast) moved their base of operations. It was not until the middle 1930's that the New England landings again exceeded the Middle Atlantic catch. This was not due to a shift from Middle Atlantic ports because the landings in these ports also increased up to 1938.

The increased landings in New England were due to the discovery of scallop beds on Georges Bank and the development of markets for the product. Most of this catch was landed in Massachusetts ports. As indicated in table 1, Massachusetts landings which had generally been well under one million pounds of scallop meats jumped to almost 5 million pounds in 1937.

Table 1 - U. S. Landings of Sea Scallops (Meats Only) by State and Region, 1889-1952

Year	New England					Middle Atlantic			Total Chesapeake1/	Total Atlantic States
	Maine	Mass.	R. I.	Conn.	Total	N. Y.	N. J.	Total		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1952	1,495,754	13,319,000 X	42,400 X	100 X	14,857,254	1,441,000 X	872,000 X	2,313,000	-	17,170,254
1951	676,803	13,565,878	67,300	200 X	14,310,181	3,300,000 X	1,000,000 X	4,300,000	-	18,610,181
1950	524,824	13,186,200	42,000	-	13,753,024	4,806,200	1,328,800	6,135,000	-	19,888,024
1949	509,000	13,468,900	-	2,100	13,980,000	3,309,200	998,600	4,307,800	-	18,287,800
1948	453,700	11,985,700	40,400	3,000	12,482,800	3,318,200	835,100	4,153,300	100	16,636,200
1947	507,100	12,524,600	1,600	6,000	13,039,300	1,441,000	173,800	1,614,800	-	14,654,100
1946	136,800	9,438,300	-	3,000	9,578,100	1,966,100	68,800	2,034,900	4,100	11,617,100
1945	71,400	3,920,200	-	2,600	3,994,200	1,648,100	68,500	1,716,600	-	5,710,800
1944	77,800	4,158,700	26,500	-	4,263,000	605,600	100	605,700	-	4,868,700
1943	232,700	4,609,500	-	-	4,842,200	686,400	300	686,700	-	5,528,900
1942	132,100	6,007,200	100	25,000	6,164,400	962,200	56,400	1,018,600	-	7,183,000
1941	**	**	**	**	**	**	**	**	**	7,864,500
1940	199,100	5,191,700	100	-	5,390,900	2,184,400	67,500	2,251,900	-	7,642,800
1939	593,500	6,584,400	-	-	7,177,900	2,590,500	20,100	2,610,600	-	9,788,500
1938	792,900	5,057,200	400	-	5,850,500	2,944,800	114,000	3,058,800	-	8,909,300
1937	679,400	4,976,900	2,700	-	5,659,000	2,818,700	234,100	3,052,800	10,800	8,722,600
1936	*	*	*	*	*	*	*	*	*	*
1935	743,200	924,300	2,600	-	1,670,100	2,213,500	426,600	2,640,100	-	4,310,200
1934	*	*	*	*	*	*	*	*	*	*
1933	1,073,172	1,029,097	-	55,926	2,158,195	1,823,492	373,589	2,197,081	72,645	4,427,921
1932	607,780	869,634	-	94,527	1,571,941	1,531,587	240,234	1,771,821	-	3,343,762
1931	586,870	493,663	-	423	1,080,956	1,097,868	154,364	1,252,232	-	2,333,188
1930	436,416	510,738	-	-	947,154	*	*	*	*	*
1929	358,570	446,280	-	-	804,850	1,610,310	56,700	1,667,010	-	2,471,860
1928	326,178	119,124	29,970	-	475,272	*	*	*	*	*
1926	*	*	*	*	*	1,067,964	47,436	1,115,400	-	*
1924	200,514	138,600	-	-	339,114	*	*	*	*	*
1919	72,512	42,300	-	-	114,812	*	*	*	*	*
1905	415,600	15,005	-	-	430,605	*	*	*	*	*
1902	114,656	19,200	-	-	133,856	*	*	*	*	*
1898	166,509	198,440	-	-	364,949	*	*	*	*	*
1889	295,299	28,550	-	-	323,849	*	*	*	*	*

1/VIRGINIA AND MARYLAND. *NO DATA AVAILABLE. **NO BREAKDOWN BY STATE OR REGION. X ESTIMATED. - NO LANDINGS REPORTED.

During World War II New England production declined, then picked up again in 1946, and increased to an all-time record of almost 15 million pounds in 1952. Most of the postwar production in New England was landed in the port of New Bedford, Massachusetts.

Table 2 - Comparison of Landings of Sea Scallops (Meats Only) at New Bedford, Mass., with Atlantic Coast States, 1938-52

Year	New Bedford	Atlantic Coast	Percentage landed at New Bedford
	(Thousands of Lbs.)		%
1952	12,110	17,170 X	70.5
1951	12,602	18,610 X	67.7
1950	11,982	19,888	60.2
1949	11,707	18,288	64.0
1948	10,082	16,636	60.6
1947	10,675	14,654	72.8
1946	8,940	11,617	77.0
1945	3,897	5,711	68.3
1944	4,009	4,869	82.3
1943	3,832	5,529	69.3
1942	5,446	7,183	75.8
1941	5,579	7,865	70.9
1940	4,414	7,643	57.8
1939	4,733	9,789	48.4
1938	4,255	8,909	47.8

X PARTIALLY ESTIMATED.

Middle Atlantic landings after the War rose to a peak of over 6 million pounds in 1950 and then declined to a little over 2 million pounds in 1952.

NEW BEDFORD LANDINGS AND FISHING AREAS

The principal scallop port for many years, especially since 1941, has been New Bedford. Landings at this port are compared with those for the entire Atlantic Coast for the years 1938 through 1952 in table 2. Most of the studies included in this report are based on an analysis of landings in New Bedford from 1944 through 1952, during which period New Bedford received from 60 to 82 percent of the total Atlantic Coast scallop production.

Scallops landed at New Bedford are taken largely from eight of the statistical subareas established by the North American Council for Fishery Investigations as revised in 1943 (Rounsefell 1948)--fig. 4. Landings from each of these areas for the years 1944 through 1952 are given in table 3.

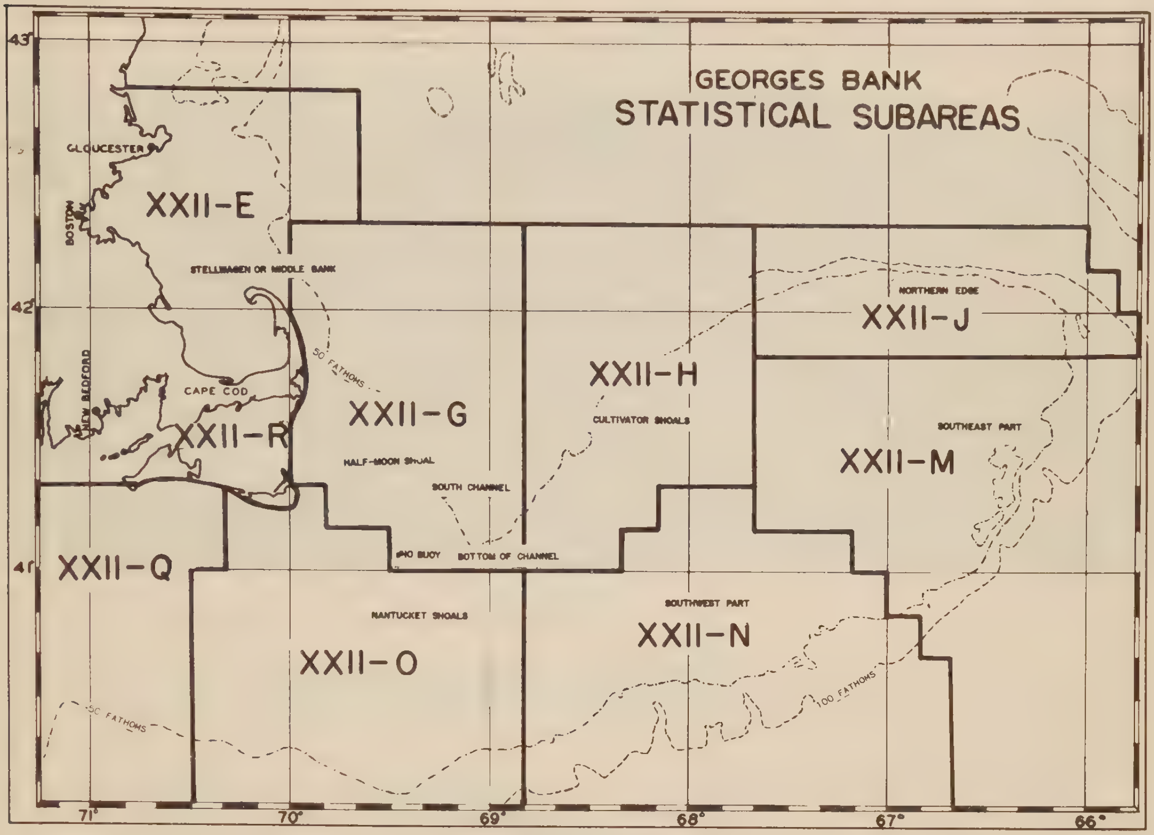
GEORGES BANK
STATISTICAL SUBAREAS
GLOUCESTER
BOSTON
XXII-E
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
XXII-R
XXII-G
50 FATHOMS
HALF-MOON SHOAL
SOUTH CHANNEL
XXII-H
CULTIVATOR SHOALS
NORTHERN EDGE
XXII-J
SOUTHEAST PART
XXII-M
XXII-Q
#10 BUOY
BOTTOM OF CHANNEL
NANTUCKET SHOALS
XXII-O
SOUTHWEST PART
XXII-N
100 FATHOMS
50 FATHOMS
43°
42°
41°
71°
70°
69°
68°
67°
66°

FIGURE 4 - REVISED STATISTICAL SUBAREAS ADOPTED IN 1943 FOR BIOSTATISTICAL DATA.

The fluctuations in the percentage contributions of the various areas to the New Bedford landings are not, of course, reliable indicators of depletion or abundance. The amount of fishing in any given area will be determined to some extent

Table 3 - New Bedford (Mass.) Landings of Sea Scallops (Meats) by Area of Catch, 1944-52

Year	Unit	Stellwagen or Middle Bank (XXII-E)	W. Side So. Channel (XXII-G)	Cultivator Shoals (XXII-H)	Northern Edge (XXII-J)	Southeast Georges (XXII-M)	Southeast Georges (XXII-N)	Nantucket Shoals (XXII-O)	Off Fire Island Inlet (XXIII)	Total All Areas
1952	Lbs.	12,109	2,773,095	36,329	5,049,698	3,172,712	823,452	242,192	-	12,109,587
	%	0.1	22.9	0.3	41.7	26.2	6.8	2.0	0.0	100.0
1951	Lbs.	126,023	1,764,319	819,148	3,516,035	1,109,000	3,730,273	1,499,671	37,807	12,602,276
	%	1.0	14.0	6.5	27.9	8.8	29.6	11.9	0.3	100.0
1950	Lbs.	203,697	2,048,955	59,910	2,180,758	2,024,989	2,743,920	2,552,205	167,751	11,982,185
	%	1.7	17.1	0.5	18.2	16.9	22.9	21.3	1.4	100.0
1949	Lbs.	81,950	2,411,676	468,286	4,237,994	152,193	468,287	3,816,536	70,243	11,707,165
	%	0.7	20.6	4.0	36.2	1.3	4.0	32.6	0.6	100.0
1948	Lbs.	30,246	1,492,107	141,145	3,770,595	2,278,488	90,736	2,086,934	191,554	10,081,805
	%	0.3	14.8	1.4	37.4	22.6	0.9	20.7	1.9	100.0
1947	Lbs.	85,400	1,366,414	1,195,612	7,525,950	96,076	-	394,979	10,675	10,675,106
	%	0.8	12.8	11.2	70.5	0.9	0.0	3.7	0.1	100.0
1946	Lbs.	44,700	563,221	992,342	4,085,588	143,040	2,369,104	742,021	-	8,940,016
	%	0.5	6.3	11.1	45.7	1.6	26.5	8.3	0.0	100.0
1945	Lbs.	-	331,230	701,430	1,987,385	136,390	116,905	545,557	77,936	3,896,833
	%	0.0	8.5	18.0	51.0	3.5	3.0	14.0	2.0	100.0
1944	Lbs.	40,088	240,529	400,881	2,325,111	400,881	120,265	481,057	-	4,008,812
	%	1.0	6.0	10.0	58.0	10.0	3.0	12.0	0.0	100.0

by the relative productivity of adjacent areas. It is, therefore, possible that a productive area may be neglected for some period of time if neighboring areas are found to be more profitably fished.

STELLWAGEN OR MIDDLE BANK (Statistical Subarea XXII-E): This area contributes very little to the landings at New Bedford. In only one of the nine years under consideration was more than 1 percent of the total catch landed from this area. The fishery on Stellwagen Bank is conducted chiefly by the smaller vessels operating out of Provincetown and other Cape Cod ports.

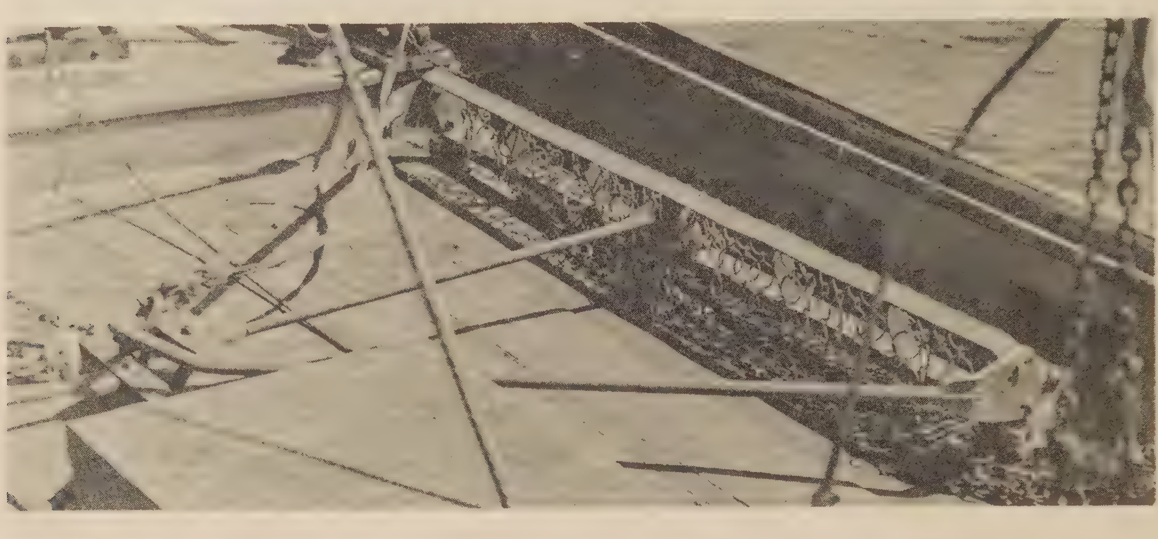

FIGURE 5 - A TYPICAL SCALLOP DREDGE USED BY NEW BEDFORD DRAGGERS.

WESTERN SIDE OF SOUTH CHANNEL (Statistical Subarea XXII-G): The beds in this area are located in the vicinity of #10 Buoy, Half-Moon Shoal, and along the Bottom of South Channel. In 1944, 6 percent of the total catch came from this area. In subsequent years, the contribution of this area increased, until more than 20 percent of the total came from here in 1949. The production from this area decreased slightly in 1950 and 1951, and then increased again in 1952, with almost 23 percent of the catch originating here in that year.

CULTIVATOR SHOALS (Statistical Subarea XXII-H): This ground contributed 10 percent of the catch in 1944, 18 percent in 1945, and about 11 percent in each of the next two years. Subsequent years saw only minor landings from this area. An increase was noted in 1951, when more than 6 percent of the total catch came from this area, but in 1952 the catch from this ground dropped again.

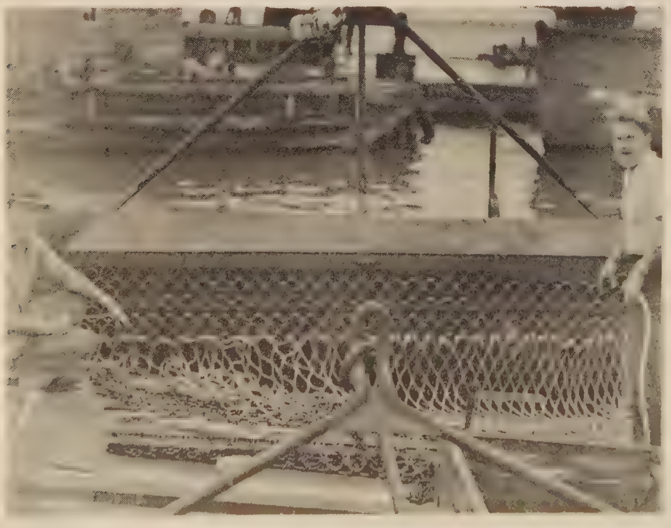

FIGURE 6 - THE DRAGGER ARNOLD BEING FITTED WITH A NEW SCALLOP DREDGE AT A NEW BEDFORD SHIPYARD.

NORTHERN EDGE (Statistical Subarea XXII-J): In the earlier years, 1944-47, this was the most important scallop area, accounting for 45 to 70 percent of the catch. In each of the next two years, 1948 and 1949, this area contributed between 36 and 37 percent of the catch, and in 1950 about 18 percent. During the next two years production increased. In 1952 over 40 percent of the total catch came from here.

SOUTHEAST GEORGES (Statistical Subarea XXII-M): These beds accounted for 10 percent of the total catch in 1944, but in subsequent years a considerable decline in landings was noted, until 1947 when less than 1 percent of the total catch came from here. In 1948 there was a tremendous increase, with almost 23 percent of the total catch coming from these beds. In following years the landings from this area varied greatly, declining to about 1 percent in 1949 and jumping to over 26 percent of the New Bedford landings in 1952.

SOUTHWEST GEORGES (Statistical Subarea XXII-N): Only 3 percent of the catch was landed from this area in 1944 and 1945, but in 1946 more than 26 percent of the total originated here. The next two years landings from this area were practically nil. In 1949, 4 percent came from this area, and in 1950 and 1951, 23 and 30 percent, respectively. In 1952 less than 7 percent of the New Bedford catch originated here.

NANTUCKET SHOALS (Statistical Subarea XXII-O): During 1944-46, the contribution of this area fluctuated between 8 and 14 percent. In 1947 it dropped to less than 4 percent. From 1948-50, the contribution of this area ranged from about 21 to 33 percent. The following two years the contribution of these beds declined to about 12 percent in 1951 and 2 percent in 1952.

OFF FIRE ISLAND INLET (Statistical Area XXIII): These beds off Long Island, SE. of Ambrose Light, are fished very little by the New Bedford fleet, but have been important to the New York scallop fleet. In none of the years, 1944-52, does the contribution of these beds exceed 2 percent of the total scallop catch landed at New Bedford.

ABUNDANCE

Landings alone do not tell us much about the relative abundance of scallops on the grounds. Landings have been artifically controlled by agreements among the fishermen. The union has prescribed a catch limit of 100 gallons (900 pounds) of scallop meats per man per trip during most of the period of this study. In the early part of the period the limit was 150 gallons (1,350 pounds). The union rules

Table 4 - Abundance Index (Catch Per-Unit-Of-Effort) for the New Bedford Sea-Scallop Fleet, 1944-52[1/]

Year	Quantity Hailed (Meats)	Trips	Days Fished	Avg. No. of Days Fished Per Trip	Catch Per Boat Per Day (Meats)
	Lbs.	No.	No.	No.	Lbs.
1952	12,149,200	1,393	7,792.6	5.6	1,559
1951	12,496,346	1,478	7,537.0	5.1	1,658
1950	11,587,329	1,393	7,040.0	5.1	1,646
1949	11,214,468	1,494	8,072.8	5.4	1,389
1948	9,510,732	1,404	7,205.1	5.1	1,320
1947	10,519,335	1,435	6,301.0	4.4	1,669
1946	7,586,775	766	4,238.0	5.5	1,790
1945	2,813,544	296	1,717.2	5.8	1,638
1944	3,093,462	325	1,711.6	5.3	1,807

[1/] INTERVIEWED VESSELS ONLY.

further required that boats engage in actual fishing operations for not more than 8 days and that they remain in port 2 to 4 days between trips. However, these regulations have not been in force since the latter part of 1952.

Throughout the period of this study the scallop boats were able to catch the established limit in less than eight days, except during periods of unfavorable weather. We are thus afforded two measures of abundance: the catch per-unit-of-effort and the number of fishing days required to catch the prescribed limit.

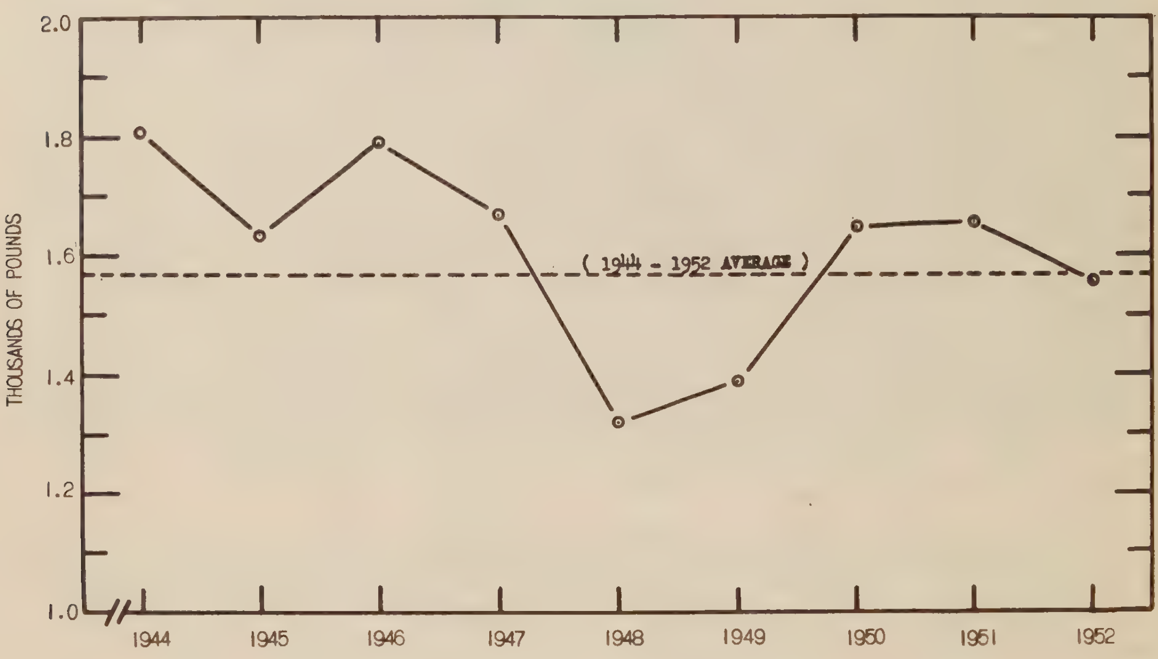

FIGURE 7 - CATCH PER BOAT PER DAY (IN THOUSANDS OF POUNDS) FOR THE NEW BEDFORD SEA-SCALLOP FLEET, 1944-52.

The first index, catch per boat per day, is shown in the last column of table 4 and is plotted in fig. 7. It will be noted that this index varies very little throughout the period of study except for the years 1948 and 1949 when the index was somewhat lower.

The other index, average number of days fished per trip, was also remarkably uniform (column 5, table 4).

One must conclude from these data that there has not been a serious depletion of scallops in the Atlantic banks considering the area as a whole. It must be borne in mind that these figures are for landings at New Bedford regardless of area fished.

Since the fleet shifts its effort from place to place in order to continue operations in the best fishing areas it is desirable to examine abundance indexes according to particular regions.

In table 5 are tabulated the catches per day for statistical subareas from 1944 through 1952. The outstanding feature of this table is the uniformity of catch per day throughout the various areas and years. Most catches are between 1,200 and 1,800 pounds per day. In only two areas did the catch per day drop below 1,000 pounds during the nine-year period--Stellwagen Bank for three years and off Fire Island Inlet in 1947, but these areas were never important to the New Bedford fleet. Neither area contributed as much as 2 percent of the catch during the study period.

One possibly significant fact emerges from the data in this table. The two years, 1948 and 1949, which were low years in the index calculated for all banks, are years in which the index is generally low for each area. It might possibly mean that factors which control the abundance of scallops in one particular area have similar effects throughout the entire area of Georges Bank and Nantucket Shoals.

Table 5 - Catch Per Day of Sea Scallops (Meats) by Area, 1944-52

Fishing Area	1952	1951	1950	1949	1948	1947	1946	1945	1944
	....	....	....	....	(Pounds)	....	....	....	....
Stellwagen or Middle Bank (XXII-E)	820	1,231	1,286	1,021	906	945	1,102	1/	1,022
W. Side South Channel (XXII-G)	1,484	1,518	1,456	1,350	1,229	1,436	1,365	1,670	1,768
Cultivator Shoals (XXII-H) ..	1,505	1,680	1,463	1,525	1,336	1,642	1,677	1,624	1,609
Northern Edge (XXII-J)	1,577	1,714	1,606	1,364	1,307	1,734	1,870	1,698	1,886
Southeast Georges (XXII-M) ..	1,633	1,802	1,658	1,411	1,392	1,626	1,782	1,727	1,842
Southwest Georges (XXII-N) ..	1,502	1,623	1,766	1,323	1,260	1/	1,990	1,633	2,054
Nantucket Shoals (XXII-O) ...	1,474	1,764	1,806	1,456	1,389	1,794	1,505	1,456	1,596
Off Fire Island Inlet (XXIII)	1/	1,081	1,319	1,026	1,035	450	1/	1,080	1/

1/INSUFFICIENT FISHING TO COMPUTE A RELIABLE INDEX.

There is no evidence, however, that any areas were overfished during this period. If one area could not provide the catch limit in a few days' fishing, other areas were found that could. Thus the effort in any one area was adjusted to its productive capacity. The result is that catch-per-day was maintained for all important areas.

The relative abundance of scallops in the area fished by the New Bedford fleet during the nine-year period are shown graphically in figures 8a-8i. In the analysis of the interview data, catch per day was computed for each unit area (areas bounded by 10 minutes of latitude and 10 minutes of longitude). These figures (8a-8i) show very clearly how the areas fished fluctuated from year to year. In no two years were exactly the same beds fished. There was a constant shifting from one area to another but Georges Bank as a whole maintained its productive capacity (with a slight recession in 1947 and 1948).

The only conclusion that can be drawn from the above studies is that there has been no over-all depletion of scallops on Georges Bank and nearby areas. Although individual beds may have been fished out, there have always been other beds available to insure all vessels catching their limits. The value of the catch limit in the conservation of the sea scallop cannot be assessed at this time. Whether the banks could have withstood greater fishing pressure during the past nine years will always be a matter of conjecture.

THE FUTURE OF THE SCALLOP FISHERY

These studies of catch and effort records show that there has not been any serious depletion of scallop grounds up to 1953. The question of how long the beds can withstand present fishing intensity or whether they can withstand an expanded fishery cannot be answered from catch and effort statistics alone. To answer these questions it is necessary to have certain biological facts concerning the species. Unfortunately the necessary facts are lacking in the case of the Georges Bank scallop fishery.

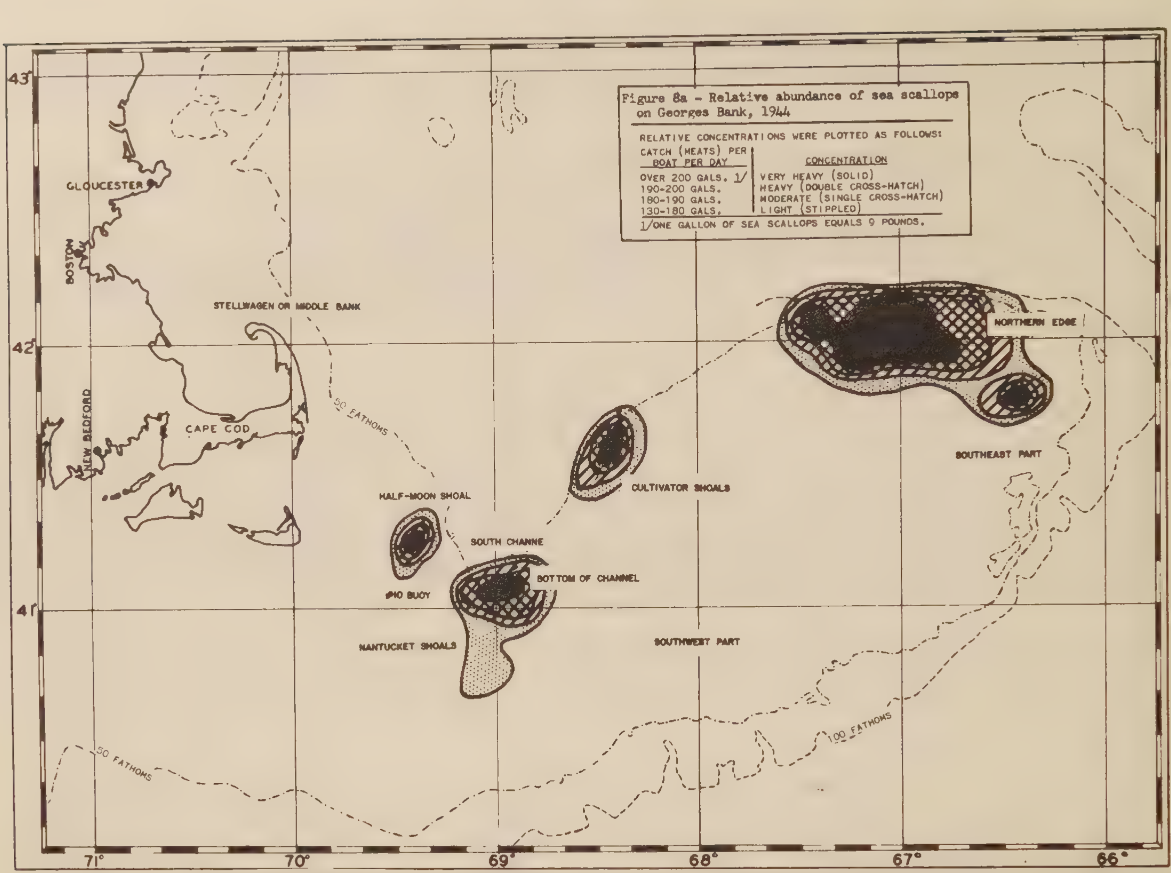
Figure 8a - Relative abundance of sea scallops on Georges Bank, 1944

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:
CATCH (MEATS) PER BOAT PER DAY
CONCENTRATION
OVER 200 GALS. 1/ VERY HEAVY (SOLID)
190-200 GALS. HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS. MODERATE (SINGLE CROSS-HATCH)
130-180 GALS. LIGHT (STIPPLED)
1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.
43°
42°
41°
71°
70°
69°
68°
67°
66°
GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
HALF-MOON SHOAL
SOUTH CHANNE
BOTTOM OF CHANNEL
#10 BUOY
NANTUCKET SHOALS
CULTIVATOR SHOALS
SOUTHWEST PART
NORTHERN EDGE
SOUTHEAST PART
100 FATHOMS
50 FATHOMS

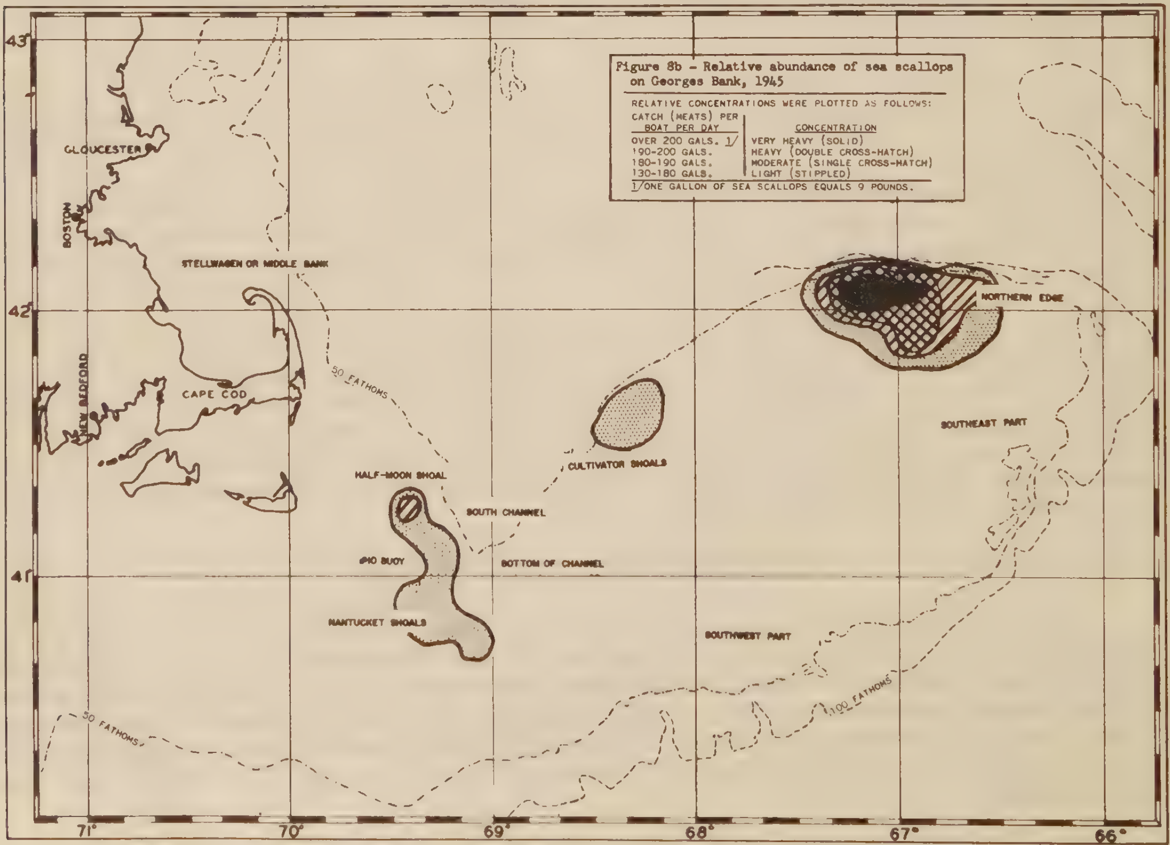
Figure 8b - Relative abundance of sea scallops on Georges Bank, 1945

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:
CATCH (MEATS) PER BOAT PER DAY
CONCENTRATION
OVER 200 GALS. 1/ VERY HEAVY (SOLID)
190-200 GALS. HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS. MODERATE (SINGLE CROSS-HATCH)
130-180 GALS. LIGHT (STIPPLED)
1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.
43°
42°
41°
71°
70°
69°
68°
67°
66°
GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
HALF-MOON SHOAL
SOUTH CHANNEL
#10 BUOY
BOTTOM OF CHANNEL
NANTUCKET SHOALS
CULTIVATOR SHOALS
SOUTHWEST PART
NORTHERN EDGE
SOUTHEAST PART
100 FATHOMS
50 FATHOMS

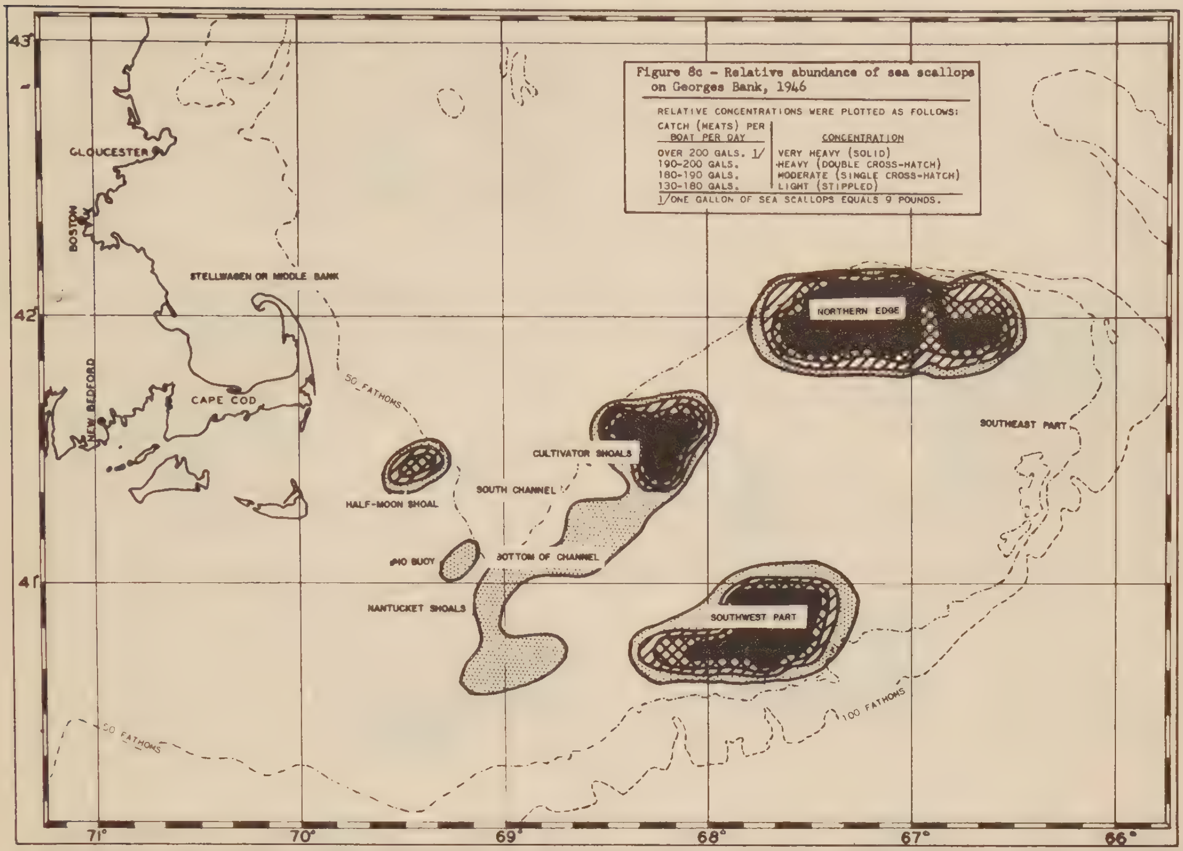

Figure 8c - Relative abundance of sea scallops on Georges Bank, 1946

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:
CATCH (MEATS) PER BOAT PER DAY | CONCENTRATION
OVER 200 GALS. 1/ | VERY HEAVY (SOLID)
190-200 GALS. | HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS. | MODERATE (SINGLE CROSS-HATCH)
130-180 GALS. | LIGHT (STIPPLED)
1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.
43°
42°
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GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
NORTHERN EDGE
CULTIVATOR SHOALS
SOUTHEAST PART
HALF-MOON SHOAL
SOUTH CHANNEL
#10 BUOY
BOTTOM OF CHANNEL
NANTUCKET SHOALS
SOUTHWEST PART
100 FATHOMS
50 FATHOMS

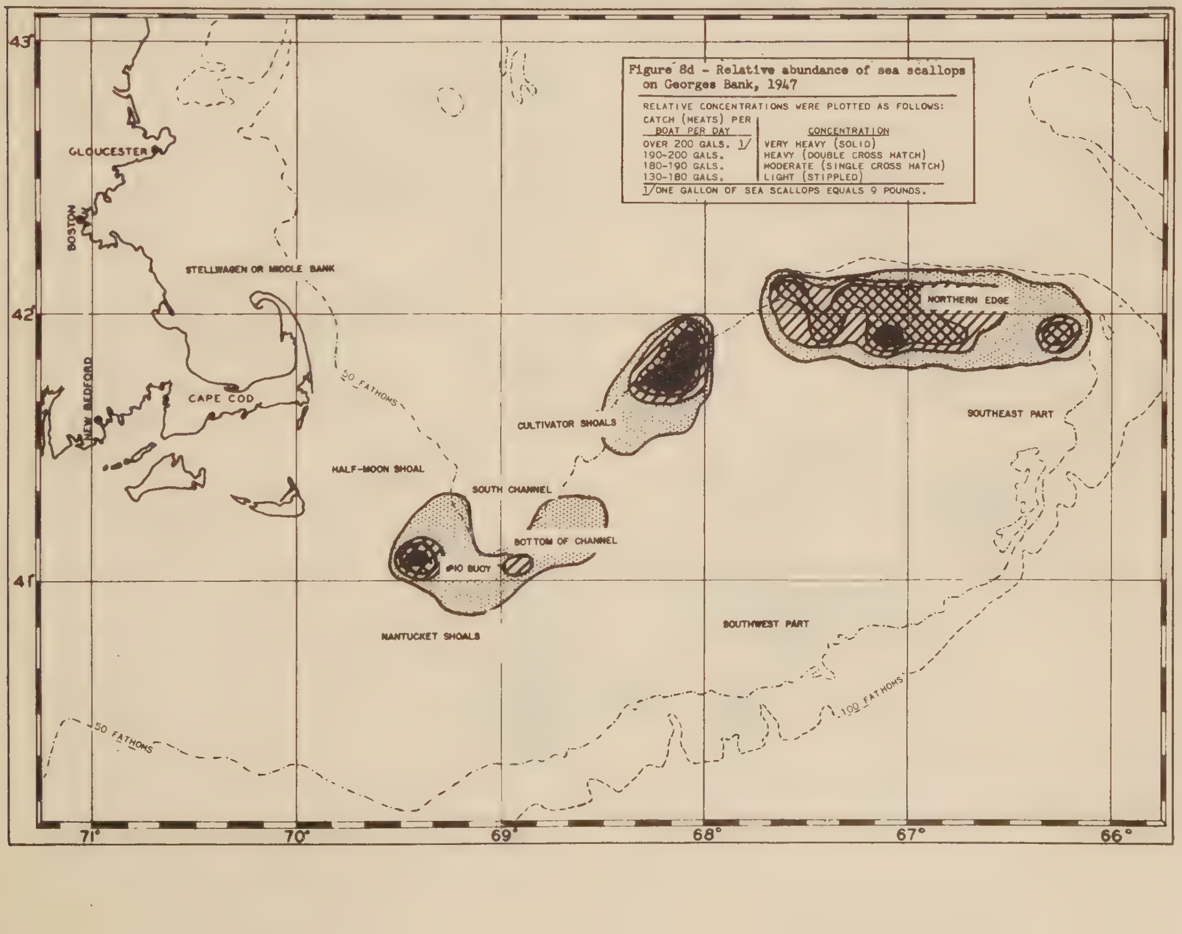

Figure 8d - Relative abundance of sea scallops on Georges Bank, 1947

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:
CATCH (MEATS) PER BOAT PER DAY | CONCENTRATION
OVER 200 GALS. 1/ | VERY HEAVY (SOLID)
190-200 GALS. | HEAVY (DOUBLE CROSS HATCH)
180-190 GALS. | MODERATE (SINGLE CROSS HATCH)
130-180 GALS. | LIGHT (STIPPLED)
1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.
43°
42°
41°
71°
70°
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68°
67°
66°
GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
NORTHERN EDGE
SOUTHEAST PART
CULTIVATOR SHOALS
HALF-MOON SHOAL
SOUTH CHANNEL
BOTTOM OF CHANNEL
#10 BUOY
NANTUCKET SHOALS
SOUTHWEST PART
100 FATHOMS
50 FATHOMS

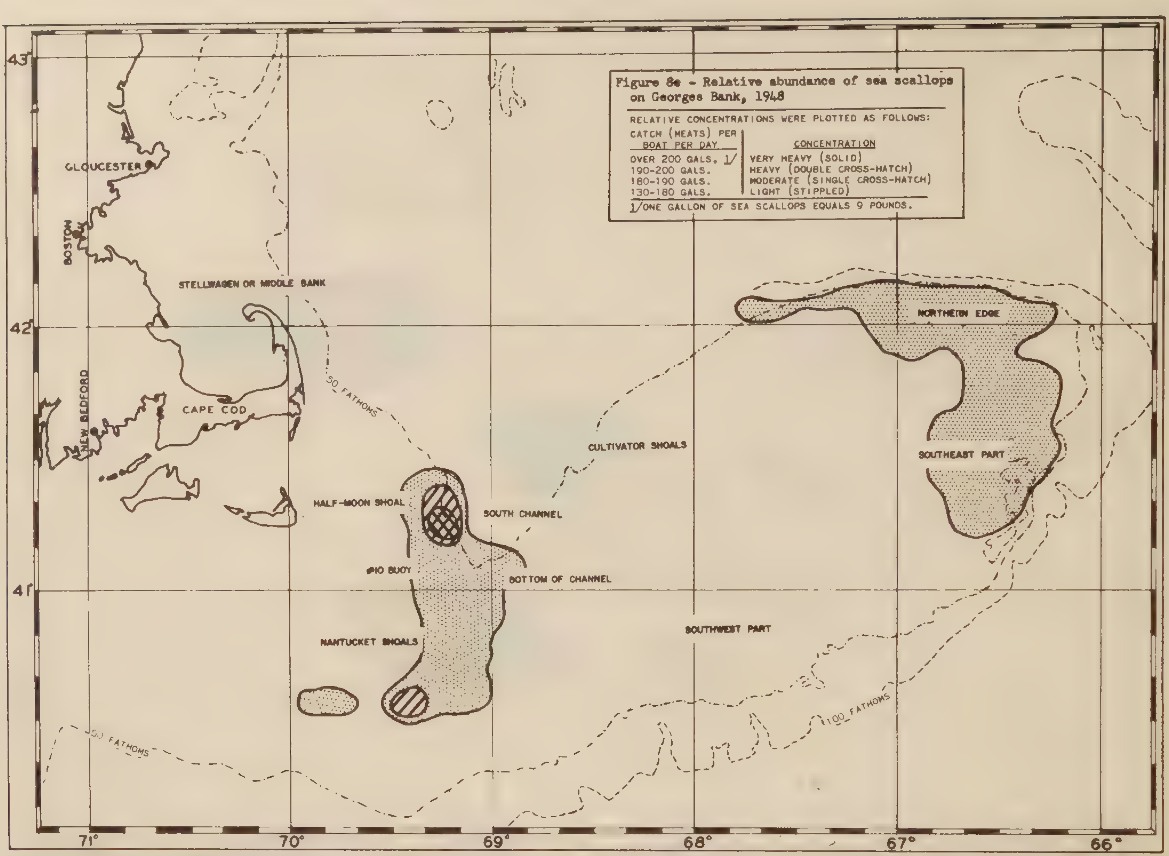

Figure 8e - Relative abundance of sea scallops on Georges Bank, 1948

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:
CATCH (MEATS) PER BOAT PER DAY
CONCENTRATION
OVER 200 GALS. 1/ VERY HEAVY (SOLID)
190-200 GALS. HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS. MODERATE (SINGLE CROSS-HATCH)
130-180 GALS. LIGHT (STIPPLED)
1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.
43°
42°
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GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
CULTIVATOR SHOALS
HALF-MOON SHOAL
SOUTH CHANNEL
#10 BUOY
BOTTOM OF CHANNEL
NANTUCKET SHOALS
SOUTHWEST PART
100 FATHOMS
50 FATHOMS
NORTHERN EDGE
SOUTHEAST PART

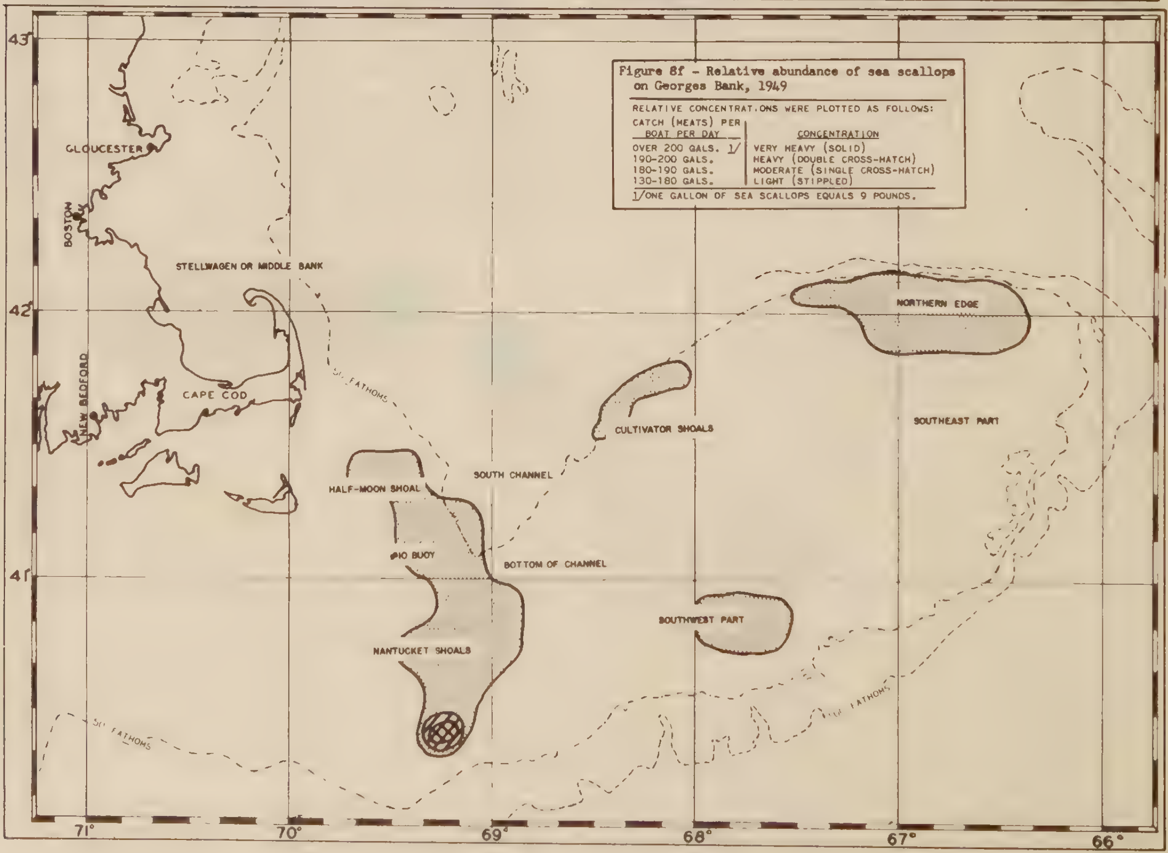

Figure 8f - Relative abundance of sea scallops on Georges Bank, 1949

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:
CATCH (MEATS) PER BOAT PER DAY
CONCENTRATION
OVER 200 GALS. 1/ VERY HEAVY (SOLID)
190-200 GALS. HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS. MODERATE (SINGLE CROSS-HATCH)
130-180 GALS. LIGHT (STIPPLED)
1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.
43°
42°
41°
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68°
67°
66°
GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
CULTIVATOR SHOALS
SOUTH CHANNEL
HALF-MOON SHOAL
#10 BUOY
BOTTOM OF CHANNEL
NANTUCKET SHOALS
SOUTHWEST PART
100 FATHOMS
50 FATHOMS
NORTHERN EDGE
SOUTHEAST PART

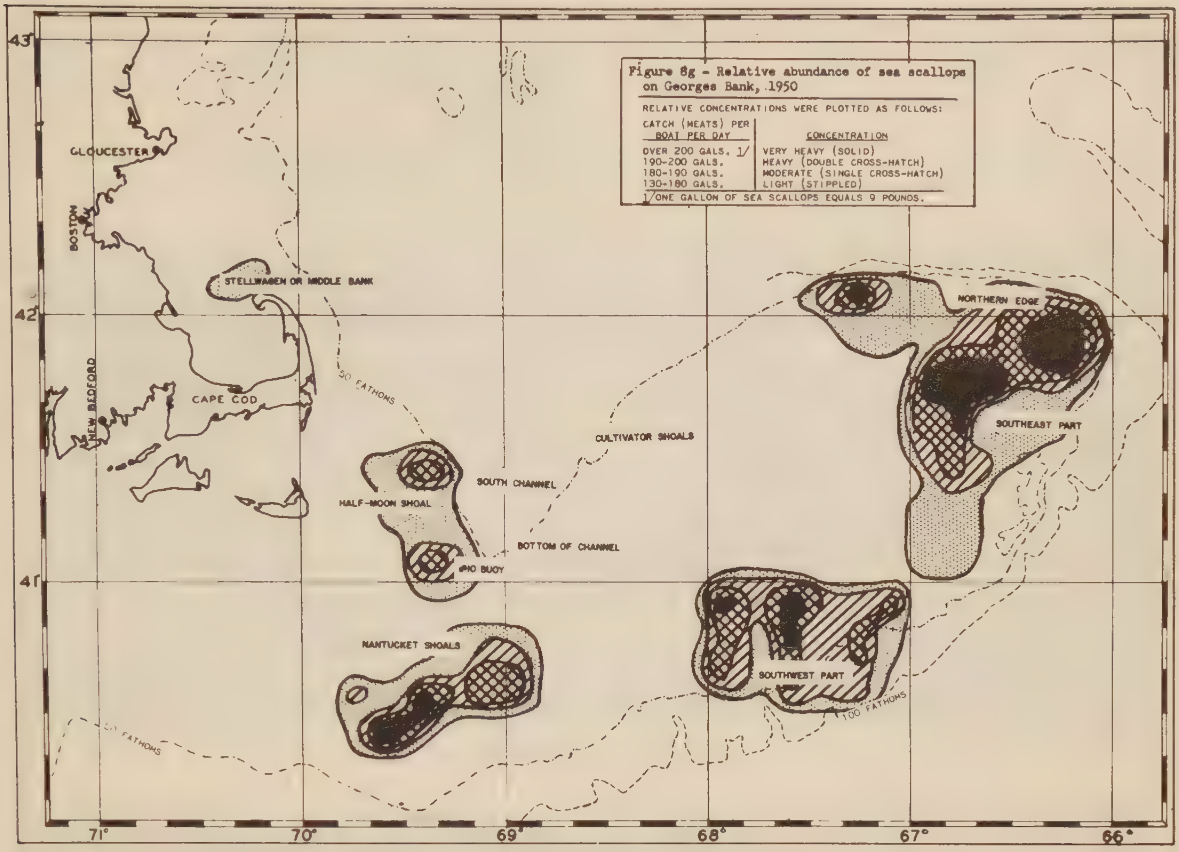
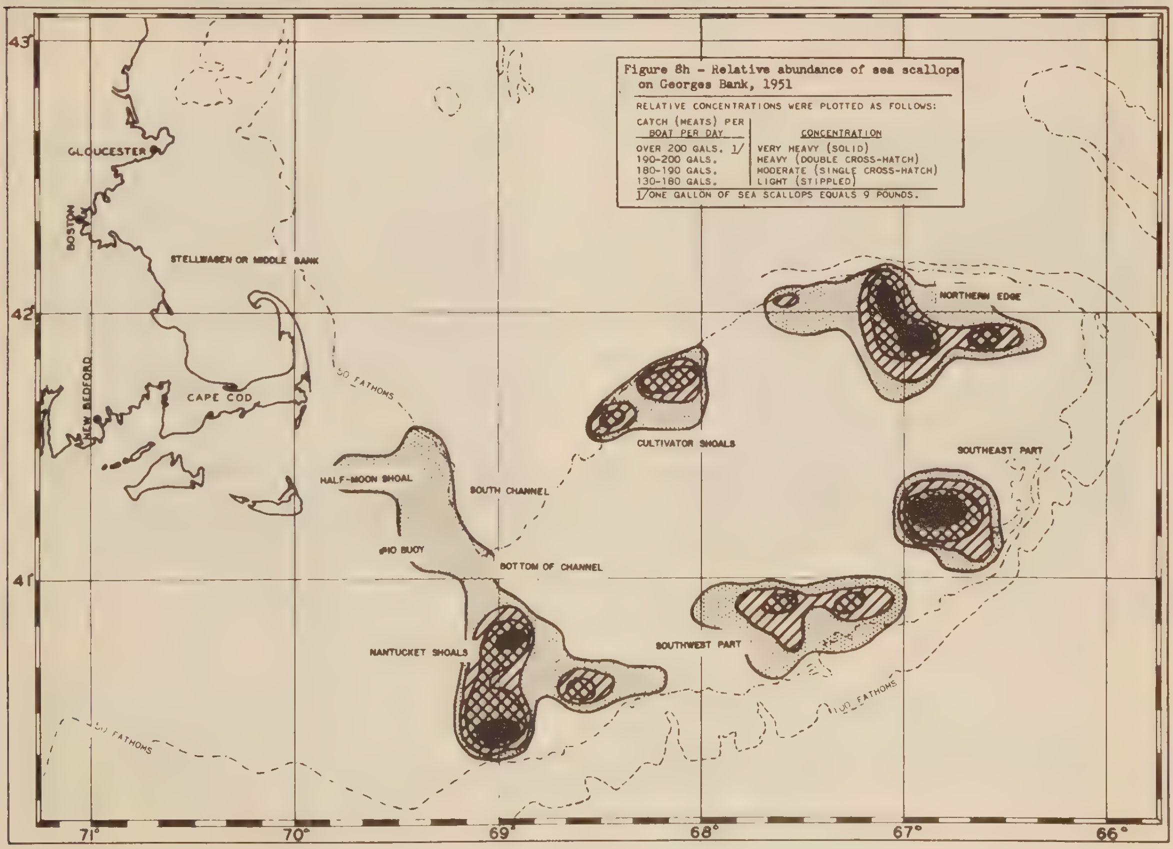

43°
42°
41°
GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
CULTIVATOR SHOALS
SOUTH CHANNEL
HALF-MOON SHOAL
BOTTOM OF CHANNEL
#10 BUOY
NANTUCKET SHOALS
NORTHERN EDGE
SOUTHEAST PART
SOUTHWEST PART
100 FATHOMS
50 FATHOMS
71°
70°
69°
68°
67°
66°

Figure 8g - Relative abundance of sea scallops on Georges Bank, 1950

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:

CATCH (MEATS) PER BOAT PER DAY	CONCENTRATION
OVER 200 GALS. 1/	VERY HEAVY (SOLID)
190-200 GALS.	HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS.	MODERATE (SINGLE CROSS-HATCH)
130-180 GALS.	LIGHT (STIPPLED)

1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.


43°
42°
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GLOUCESTER
BOSTON
STELLWAGEN OR MIDDLE BANK
NEW BEDFORD
CAPE COD
50 FATHOMS
CULTIVATOR SHOALS
HALF-MOON SHOAL
SOUTH CHANNEL
#10 BUOY
BOTTOM OF CHANNEL
NANTUCKET SHOALS
NORTHERN EDGE
SOUTHEAST PART
SOUTHWEST PART
100 FATHOMS
50 FATHOMS
71°
70°
69°
68°
67°
66°

Figure 8h - Relative abundance of sea scallops on Georges Bank, 1951

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:

CATCH (MEATS) PER BOAT PER DAY	CONCENTRATION
OVER 200 GALS. 1/	VERY HEAVY (SOLID)
190-200 GALS.	HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS.	MODERATE (SINGLE CROSS-HATCH)
130-180 GALS.	LIGHT (STIPPLED)

1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.

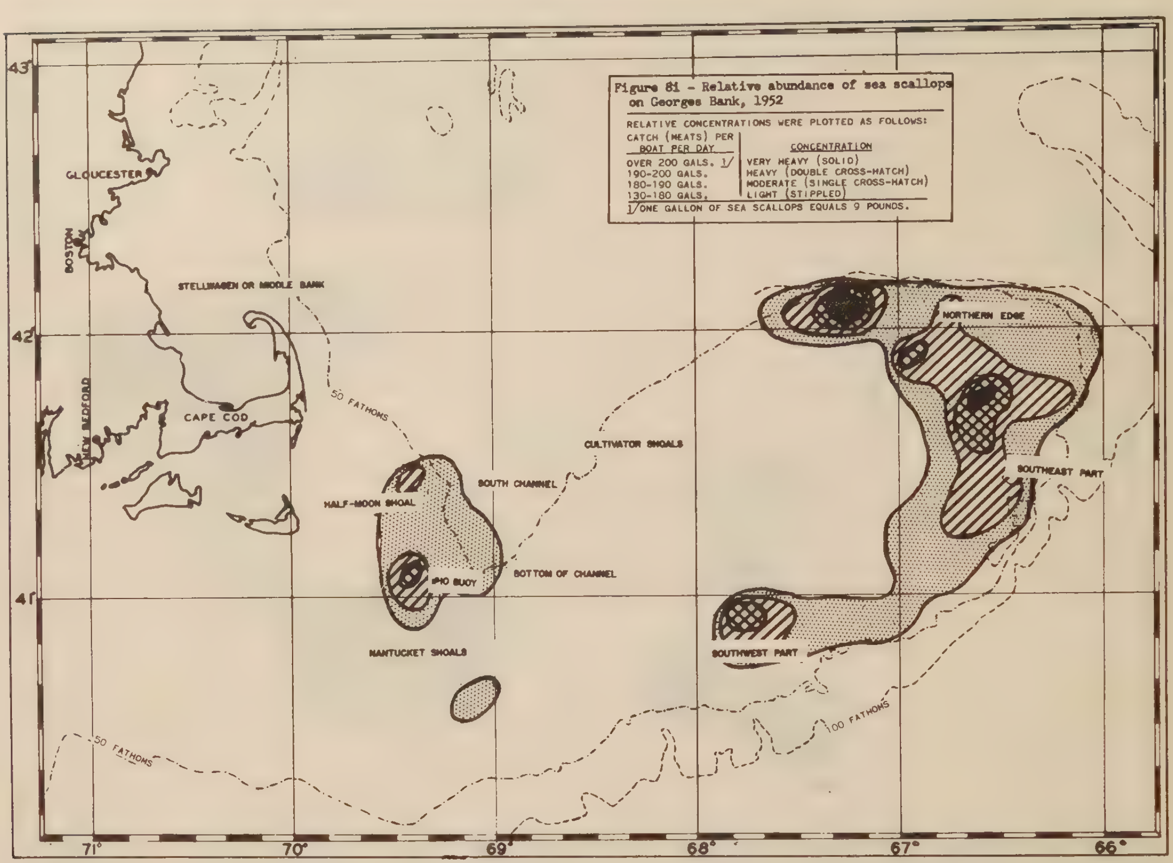

Figure 81 - Relative abundance of sea scallops on Georges Bank, 1952

RELATIVE CONCENTRATIONS WERE PLOTTED AS FOLLOWS:

CATCH (MEATS) PER BOAT PER DAY	CONCENTRATION
OVER 200 GALS. 1/	VERY HEAVY (SOLID)
190-200 GALS.	HEAVY (DOUBLE CROSS-HATCH)
180-190 GALS.	MODERATE (SINGLE CROSS-HATCH)
130-180 GALS.	LIGHT (STIPPLED)

1/ONE GALLON OF SEA SCALLOPS EQUALS 9 POUNDS.

43°
42°
41°
71°
70°
69°
68°
67°
66°
GLOUCESTER
BOSTON
NEW BEDFORD
STELLWAGEN OR MIDDLE BANK
CAPE COD
50 FATHOMS
CULTIVATOR SHOALS
SOUTH CHANNEL
HALF-MOON SHOAL
BOTTOM OF CHANNEL
P10 BUOY
NANTUCKET SHOALS
NORTHERN EDGE
SOUTHEAST PART
SOUTHWEST PART
100 FATHOMS
50 FATHOMS

The Canadians have learned much about the Digby scallops (Dickie 1950, 1951, 1952, and Medcof 1948, 1952) but this information cannot be applied to the same species in other areas. As the result of these studies, there is reasonably good information available on growth rates, age composition of the stock, catches, and fishing effort for the Canadian fishery.

Canadian scientists have found it possible to relate changes in landings directly to changes in abundance, and abundance in turn to variation in bottom water temperature. Periods of high and low abundance correspond fairly well with periods of warm and cold water, respectively, indicating that water temperature during the spawning season is a major factor in regulating the abundance of seed scallops produced in any year and landings of the fishery years later when these scallops reach commercial size. Canadian biologists claim they will be able to forecast periods of high and low abundance.

The Canadians also claim that protection of small scallops maintains the yield of the fishery at a higher long-term level than would unrestricted fishing. Canada has prescribed a legal size limit of 4 inches (shell diameter) for many years. This limit has proved difficult to enforce because scallops are shucked at sea and the shells discarded. Canadian scientists have, therefore, begun work on scallop savings gear to facilitate the escape of undersized individuals.

Posgay (1950) has summarized our knowledge of the biology of the Georges Bank stocks. Basic information necessary for the conservation of the stocks is lacking.

The spawning season is uncertain. The sexes are separate and fertilization takes place in the water. Ripe males and females are found from early spring until fall and can be induced to spawn in the laboratory, but the normal spawning time in nature in various areas remains to be determined. Posgay (personal communication) found spawning on Stellwagen Bank in September.

The fertilized eggs develop into a planktonic larva which drifts about with the currents. After a time it develops the characteristics of the adult and settles down on the bottom. It is important to know how long this larval life lasts in order to determine how far the larvae might drift from their point of origin. This information is not available. It is certain however that beds regularly swept by currents are not self perpetuating. Posgay is of the belief that beds located on Stellwagen Bank are the result of spawnings along the Maine Coast and that spawn from Stellwagen Bank is probably carried out toward Georges Bank. He states, however, that beds on Georges Bank may be self perpetuating because of a large circular eddy which develops there in the summer which might tend to hold the larvae there until they assume the adult mode of existence.

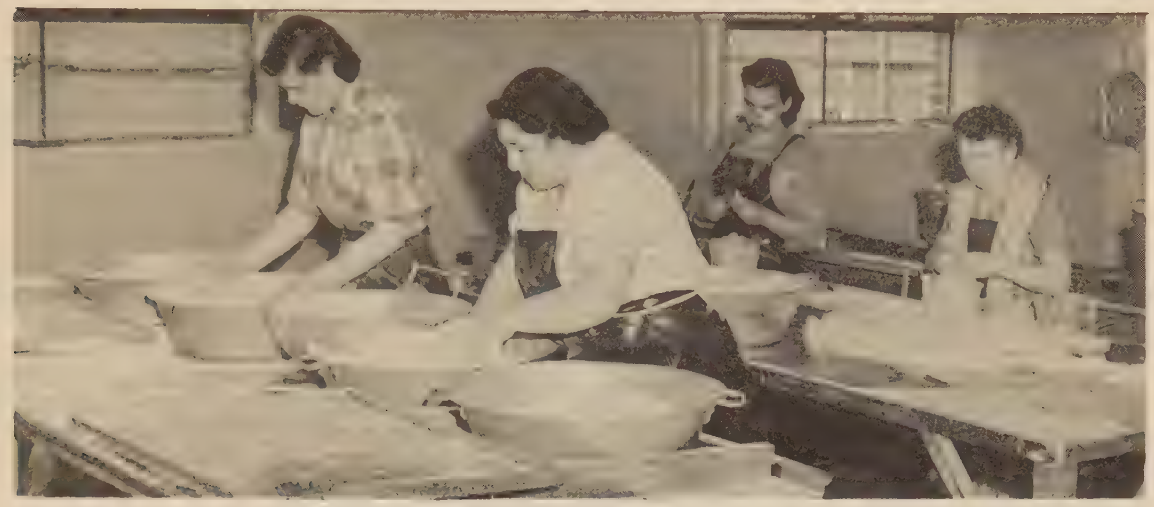

FIG. 9 - PREPARING SCALLOP MEATS FOR DEEP FRYING IN THE PLANT OF A LEADING NEW BEDFORD FIRM.

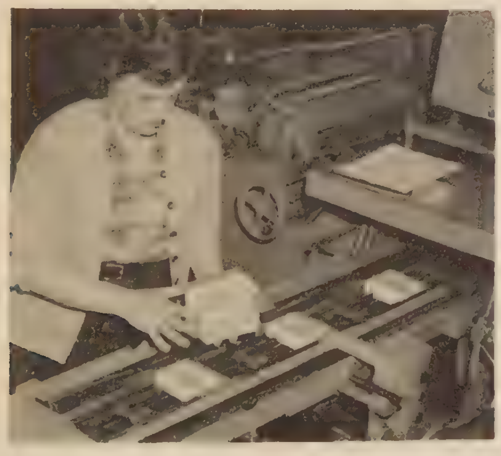

FIG. 10 - CLEANED RAW SCALLOP MEATS OR PRE-COOKED SCALLOPS ARE PACKED IN CONSUMER-SIZE (10 OZ.) PACKAGES PRIOR TO FREEZING. AUTOMATIC WRAPPING AND SEALING MACHINE IN OPERATION.

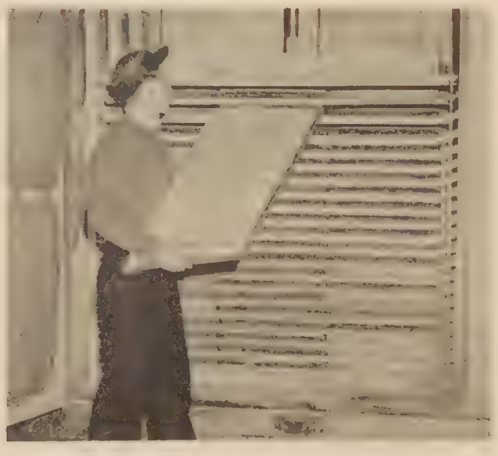

FIG. 11 - PLATE-TYPE QUICK FREEZER IS USED BY A LEADING NEW BEDFORD FIRM FOR FREEZING CONSUMER PACKAGED SCALLOP MEATS.

The age and growth of Georges Bank scallops are imperfectly known. The concentric rings which in some molluscs (including the sea scallop in Canada) reveal the annual growth have in our sea scallops never been satisfactorily interpreted in relation to age. An alternative method of determining growth is by repeated examination and measurement of samples taken from the same population. This method might be used in the case of scallops, but would require the use of a research vessel for repeated samplings seasonally for several years.

Posgay is of the opinion that our sea scallop grows to a length of about 40 mm. (1½ inches) in the first year, 80 mm. (3-1/8 inches) in the second year, 110 mm. (4-1/3 inches) the third year, and thereafter grows more slowly. His estimates, however, are based on very sketchy evidence. We do not yet have sufficient information on growth to hazard an opinion on how long it would take a new set to reach commercial size.

Conversely, we do not know the natural mortality rates of these shellfish. Should they be fished as soon as they are of marketable size or would it pay to leave them to grow a little larger? Without this information we cannot recommend management procedures.

The importance of motility in scallops has always been of interest. Scallops can swim quite actively by clapping their shells together. The young appear to be more active than older individuals. The scallop beds seem to be on rather loose sand, in depressions in a level surface, on the edge of a shoal, or where a sloping surface becomes steeper (Posgay 1950). Whether sea scallops actively seek such places or are concentrated there by currents is not known.

There is a belief among some fishermen that scallops have a tendency to congregate and that beds will recover if left undisturbed for a period of time. A closed season is sometimes advocated on this basis but there is no experimental evidence to substantiate this opinion. We cannot at this time predict the effect of a cessation of fishing.

An extensive tagging program might shed some light on problems of growth and migration. No large-scale project has been undertaken, although Baird (1952) tagged 2,000 scallops in the past two years and has had some returns. His results are not available. Members of the Fish and Wildlife Service tagged 198 specimens on Southwest Georges in 1949 and 200 in 1950. Only one tag has been recovered to date. The tagged specimen was taken near its release point about 2 years after tagging. It had grown 3/4-inch.

SUMMARY

United States landings of sea scallops (meats) increased from about 2 million pounds in 1929 to about 20 million pounds in 1950, and then decreased to about 17 million pounds in 1952.

Most of the postwar production of sea scallops has been landed at the port of New Bedford, Mass. An analysis of catch and effort data collected at this port from 1944 to 1952 reveals that there was no serious depletion of scallops on Georges Bank and nearby areas during that period.

The future of the scallop fishery is uncertain. The biology of the scallops fished by United States vessels is too imperfectly known to form the basis of any predictions of the effects of different intensities of fishing.

LITERATURE CITED

BAIRD, F.

1952. SCALLOP TAGGING PROGRAM IN MAINE AIMED AT INCREASING YIELD. ATLANTIC FISHERMAN, VOL. XXXIII, NO. 4 (APRIL 1952), P. 16.

BELDING, D. L.

1910. THE SCALLOP FISHERY OF MASSACHUSETTS. THE COMMONWEALTH OF MASSACHUSETTS, 155 PP., 118 FIGS.

DICKIE, L. M.

1950. ABUNDANCE CHANGES IN DIGBY SCALLOPS. FISH. RES. BD. CAN. PROG. REPT. OF THE ATL. CST. STAS., NO. 49 (APR. 1950), P. 14-17.

1952. CHANGES IN DIGBY SCALLOP LANDINGS - HOW AND WHY. FISH. RES. BD. OF CAN., PROG. REP. OF THE ATL. CST. STAS., NO. 54 (SEPT. 1952), PP. 12-18.

1951. BOUGHTON ISLAND, P.E.I., SCALLOP INVESTIGATION 1946. FISHERIES RESEARCH BOARD OF CANADA, MANUSCRIPT REPORTS OF THE BIOL. STA., NO. 415.

DREW, G. A.

1906. THE HABITS, ANATOMY, AND EMBRYOLOGY OF THE GIANT SCALLOP (*PECTEN TENUICOSTATUS*, MIGHELS). UNIV. OF MAINE STUDIES, NO. 6, 71 PP., 36 FIGS.

MEDCOF, J. C.

1949. MEAT YIELD FROM DIGBY SCALLOPS OF DIFFERENT SIZES. FISH. RES. BD. OF CAN., PROG. REPTS. OF THE ATL. BIOL. STAS., NO. 44 (JAN. 1949), PP. 6-9.

1949. DARK-MEAT AND THE SHELL DISEASE OF SCALLOPS. FISH. RES. BD. OF CAN., PROG. REPTS. OF THE ATL. BIOL. STAS., NO. 45 (APRIL 1949), PP. 3-6.

1952. MODIFICATION OF DRAGS TO PROTECT SMALL SCALLOPS. FISH. RES. BD. OF CAN., PROG. REPTS. OF THE ATL. CST. STAS., NO. 52 (JAN. 1952), PP. 8-14.

POSGAY, J. A.

1951. THIRD REPORT ON INVESTIGATIONS OF METHODS OF IMPROVING THE SHELLFISH RESOURCES OF MASSACHUSETTS. IV. INVESTIGATIONS OF THE SEA SCALLOP, *PECTEN GRANDIS*. (PREPARED BY THE WOODS HOLE OCEANOGRAPHIC INSTITUTION), COMMONWEALTH OF MASS., DEPT. OF CONSERVATION, DIV. OF MARINE FISHERIES, PP. 24-30.

ROUNSEFELL, G. A.

1948. DEVELOPMENT OF FISHERY STATISTICS IN THE NORTH ATLANTIC, U. S. DEPT. OF THE INTERIOR, FISH AND WILDLIFE SERVICE, SPEC. SCI. REPT. NO. 47, PP. 1-18, 9 FIGS.

ROYCE, W. F.

1946. GEAR USED IN THE SEA SCALLOP FISHERY. COMM. FISH. REV., VOL. 8, NO. 12 (DEC. 1946), PP. 7-11.

SMITH, H. M.

1891. THE GIANT SCALLOP FISHERY OF MAINE. BULL. OF THE U. S. FISH COMMISSION, VOL. IV FOR 1889 (PUBLISHED 1891), PP. 313-335.

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PRELIMINARY REPORT ON A COMPARISON OF THE STOCKS OF YELLOWFIN TUNA

by

W. F. Royce*

With so many people in the world looking toward tuna as a source of food and with the increased competition for the tuna fisheries by the fleets of many nations, there arises the question of the interrelationships of the tuna in widely separated parts of the oceans. Do the schools of each species migrate over thousands of miles as do some of our migratory birds, or are they relatively localized, hatching, growing, and dying within a few hundred miles ? There is also the related problem of whether or not the major species which are world-wide in distribution are composed of discrete units, each of which should be defined as a separate species.

Interest in these questions has been expressed at previous meetings of the Indo-Pacific Fisheries Council and the collection of data on the matter has been a major concern of the Tuna Sub-committee. In 1950 at the second meeting of the Council, the Tuna Sub-committee agreed that "the most urgent and fundamental problem with the tunas and one of distinctly international bearing was to determine whether the population of each important tuna species is continuous and homogeneous throughout its range, or whether it is composed of a number of independent or semi-independent units, and if so, the limits of each."

An approach to this problem through comparison of morphometric measurements had been commenced in various parts of the world and at the second meeting, the Tuna Sub-committee consisting of representatives of the United States, Indonesia, and Australia agreed that it was desirable to take the measurements according to the method of Godsil (1944) as further defined by Marr and Schaefer (1949) and that publication should include the original measurements of the individual fish.

In 1951, at the third meeting, it was reported by the Tuna Sub-committee that sets of morphometric measurements had been obtained on 2,783 specimens of 12 tuna species from 10 different parts of the Indo-Pacific region. Since this time, additional data have been collected, much of which has been made available to the Pacific Oceanic Fishery Investigations, where we have undertaken the analysis of data and the comparison of tunas from many parts of the world. It is the purpose of this report to present the first results of our analysis of the yellowfin tuna data. This species was chosen because it is one of the most important in the Indo-Pacific area, and a large amount of morphometric data is available.

Our comparisons have been greatly facilitated by the data which have been collected in several parts of the world by other workers. First and most assiduous of these was Godsil, who reported in 1948 on the measurements of 1,911 yellowfin from the Pacific coast of Central America. He followed this with a comparison of yellowfin from other parts of the Pacific in collaboration with Greenhood in 1951. Schaefer (1948) published information on the morphometric characteristics and relative growth in yellowfin tuna from Central America and followed this with a comparison of the Central American and Hawaiian yellowfin in a manuscript which is scheduled to appear soon as a Fishery Bulletin of the U.S. Fish and Wildlife Service. Schaefer and Walford (1950) made a comparison between the yellowfin tuna of Angola, Africa, and the Pacific coast of Central America.

These data have been supplemented by others from many regions of the Pacific through the efforts of members of the Indo-Pacific Fisheries Council. The data, both published and unpublished, which were used by me for the preparation of this report, are listed in table 1 and the localities are indicated in figure 1. In addition to the measurements enumerated, a few more have been recently added (too late for use in the following analysis) through the efforts of the Pacific Oceanic Fishery Investigations staff, and others from areas in the Philippine Islands were furnished by Dr. Villadolid.

In view of the Council's resolutions regarding papers, this one will be made as brief as possible. Neither a full discussion of the statistical techniques nor the detailed measurements of individual specimens will be presented here, these matters being left for future publication in a report of the U.S. Fish and Wildlife Service.

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I gratefully acknowledge the assistance of Miss Dorothy I. Y. Dung, who has carefully and assiduously performed the large number of calculations necessary for the handling of these data.

METHODS

Techniques of Measurement

All of these data have been collected according to the techniques described by Marr and Schaefer (1949). Because their paper may not be widely available in this area, it is desirable to repeat here the techniques for measuring characters which in our experience are the most useful for distinguishing the stocks of tunas. The measurements are all made in millimeters with calipers or dividers, depending upon the size of the fish and the distance to be measured. All distances are straight line. The ti
of the fixed arm of the calipers (or one point of th
dividers) is applied to the first point mentioned an
the tip of the sliding arm of the calipers (or th
other point of the dividers) is applied to the secon
point mentioned. Where a choice of sides i
involved, all measurements and counts are mad
on the left side of the fish. Fin insertions are t
be determined while holding the fin approximatel
perpendicular to the contour of the fish. Th
measurements are defined as follows :

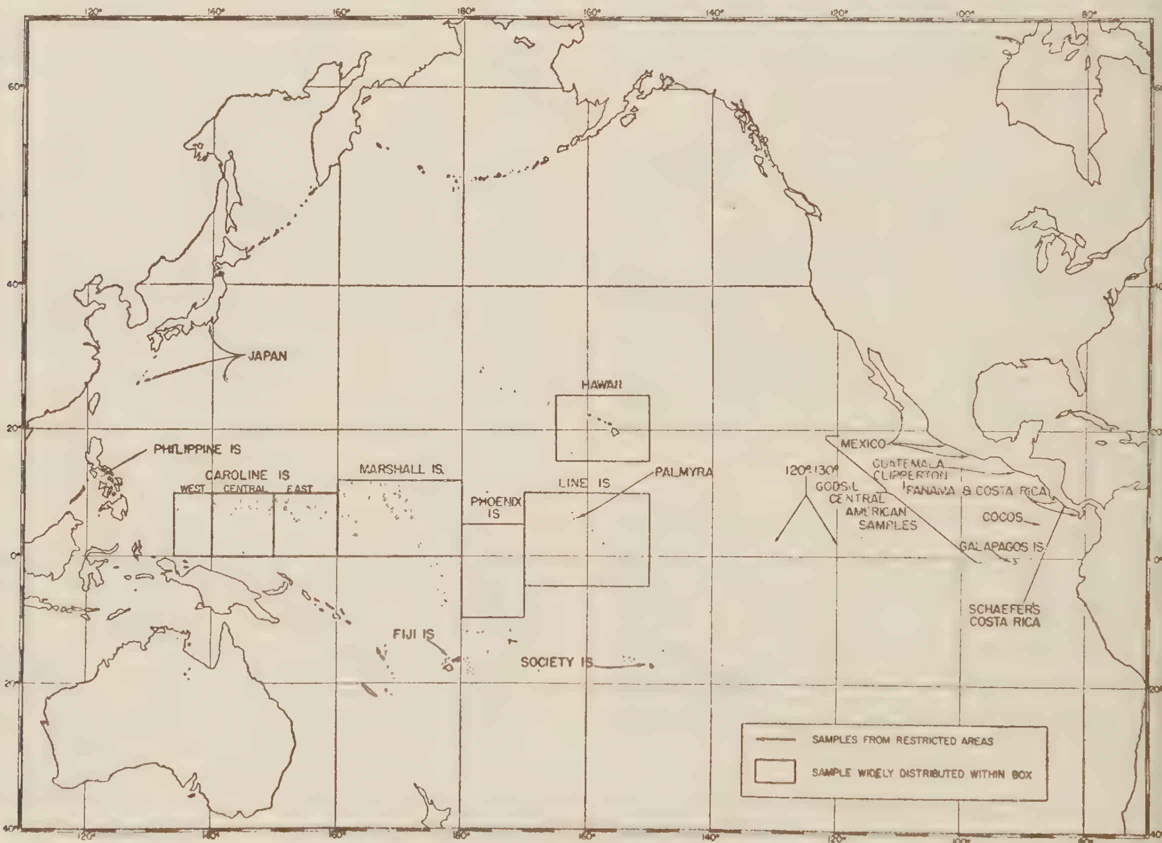
120°
140°
160°
180°
160°
140°
120°
100°
80°
60°
40°
20°
0°
20°
40°
JAPAN
HAWAII
PHILIPPINE IS
CAROLINE IS
WEST
CENTRAL
EAST
MARSHALL IS.
PHOENIX IS
LINE IS
PALMYRA
FIJI IS
SOCIETY IS
MEXICO
120° 130°
GODSIL
CENTRAL AMERICAN SAMPLES
GUATEMALA
CLIPPERTON
PANAMA & COSTA RICA
COCOS
GALAPAGOS IS.
SCHAEFER'S COSTA RICA
SAMPLES FROM RESTRICTED AREAS
SAMPLE WIDELY DISTRIBUTED WITHIN BOX

FIG. I LOCALE OF MORPHOMETRIC DATA ON YELLOWFIN TUNA

Fork length (" total length " of Marr, Schaefe
and Godsil). The distance from the tip of the snou
(most anterior point on upper jaw), with jaws close
to the cartilaginous median part of the caudal for
(seating the sliding arm of the caliper firmly an
thus depressing the small fleshy flap extendi
posteriorly).

Head length. The distance from the tip of t
snout to the most posterior point on the margin

Table 1. Locale and size of yellowfin tuna measured

Fork length *cm*	Locality																
									Equatorial Pacific (Between 10°N and 10°S latitude)								
	Angola, Africa[1]	Pacific coast of Central America[2]	Society	Hawaii[3]	Fiji[4]	Japan	Off Luzon, Philippine Is.[5]	Ceylon[6]	Costa Rica[7]	120°-130° West	Line Is.	Palmyra[4] (One of Line Is.)	Phoenix Is.	Marshall Is.[8]	Eastern Caroline Is.	Central Caroline Is.	Western Caroline Is.
20— 29.9																	
30— 39.9						1											
40— 49.9	1	7	2	16		11	1				1				1	1	
50— 59.9		336	15	15	1	6	59		2		2	1	4	21	8	6	
60— 69.9		551	3	3	2	6	122	1	7		9	10	18	6	23	11	2
70— 79.9	11	597	2	2		8	62	1	3		25	24	14	4	18	19	1
80— 89.9	11	194	8	4	3	8	47	1	6		30	18	16	5	19	21	1
90— 99.9	1	84	1	9	1	6	19		11	1	31	27	19	4	16	21	3
100—109.9		46		15	6	1	9		6		31	10	10	3	6	33	
110—119.9	9	50		6			6		6		21	2	24	1	14	27	2
120—129.9	8	24		17			15		2	3	17	1	13		12	33	7
130—139.9	9	13		29			11			5	19		8		21	24	1
140—149.9	6	5	2	22			5		2	17	24	1	3		9	13	
150—159.9	2	4		15			2		1	13	39				11	2	
160—169.9	2			32						4	6		1		1		
170—179.9				18													
180—189.9																	
Total ..	60	1,911	33	203	13	47	358	3	46	43	255	94	130	44	159	211	17

Sources : [1] Schaefer and Walford (1950).
[2] Godsil (1948).
[3] Schaefer (MS).
[4] Godsil and Greenhood (1951).
[5] Measurements supplied by Dr. D. V. Villadolid.
[6] Measurements by Mr. E. R. A. de Zylva.
[7] Schaefer (1948).
[8] Measurements supplied by Mr. J. C. Marr, Fish and Wildlife Service, Stanford, California. Partly collected near Bikini Atoll, which is at 12°N. latitude.

All other data collected by staff of Pacific Oceanic Fishery Investigations.

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the subopercle (depressing the fleshy flap extending posteriorly).

Snout to insertion first dorsal. The distance from the tip of the snout to the insertion of the first dorsal. The insertion of the first dorsal is the intersection of the anterior margin of the first dorsal spine, when the fin is held erect, with the contour of the back. This point is identical with the most anterior point of the first dorsal fin slot.

Snout to insertion second dorsal. The distance from the tip of the snout to the insertion of the second dorsal. The insertion of the second dorsal is not so clearly defined as the insertion of the first dorsal, particularly on larger fish, but is the intersection of the anterior margin of the second dorsal, when the fin is held erect, with the contour of the back. When the second dorsal is raised, the determined point should be marked with thumb nail or scalpel.

Snout to insertion anal. The distance from the tip of the snout to the insertion of the anal. The insertion of the anal is determined in the same manner as the insertion of the second dorsal.

Snout to insertion ventral. The distance from the tip of the snout to the insertion of the ventral. The insertion of the ventral is the intersection of the anterior margin of the ventral, when the fin is extended, with the contour of the body.

Insertion ventrals to anterior edge of vent. The mid-line distance from the insertion of the ventrals to the anterior edge of the vent.

Greatest depth. The greatest distance between the dorsal and ventral contours perpendicular to the axis of the fish. The measurement is taken from the dorsal body contour to the ventral body contour, with the first dorsal fin depressed in its slot. It is oriented by reference to the dorsal spine, the insertion of which is at or nearest the upper end of the vertical. Dorsal spines are counted posteriorly, the most anterior spine being the first.

Length of pectoral. The distance from the anterior end of the fin slot to the most posterior point, taken with the pectoral fin extended posteriorly and opposed to the side.

Height (length) of second dorsal. The distance from the insertion of the second dorsal to its distal end, with the fin in a normal position. Note that this fin is often extended in a long filament, especially in large *Neothunnus*, and care should be taken to notice if this extension is frayed.

Height (length) of anal. The distance from th insertion of the anal fin to its distal end, with the fi in a normal position. Remarks under " heigh second dorsal " apply here.

Diameter of iris. The greatest diameter measure to the margin of the yellow iris and the adjoinin black tissue. This is generally not on a line paralle to the median line of the body.

Number of gill rakers. The number of anterio rakers on the most anterior gill arch on the left sid of the fish (some species also have posterior raker on this same arch). The counts of the rakers o the two arms of the arch are kept separate. Fo example, 10+20=30 gill rakers with 10 on th upper arm and 20 on the lower. The counts in clude all rakers that project above the surround ing epithelium. We have encountered no diffi culty in assigning rakers near the angle of the arc to one arm or the other.

Sex. Determined by inspection. Very immatur males and females may be difficult to distinguish Ovaries, which are tubular, may often roll betwee the fingers, while testes, which are solid, will tur over. The testes of ripening or ripe males ar enlarged, solid, white bodies, not round in cros section. The ovaries of ripening or ripe female are enlarged, turgid, pink or yellow-orange bodies round in cross section. Ova may often be dis tinguishable with the naked eye. The testes c spawned-out males are less turgid, tougher, an pinker than those not spawned, and are difficul or impossible to distinguish from maturing teste in early stages. The ovaries of spawned-ou females are hollow, more or less flabby, sac-lik tubes.

Weight. This has been determined in pound on spring balances or steelyards. Metric unit would be more desirable, and experience has show that a counterpoise style of balance, such as Chatil lon No. 160, is more satisfactory, since the cali bration of a spring balance is subject to change du to corrosion.

Analysis of Data

There are numerous practical and statistica difficulties involved in the analysis of morpho metric data. Since most of the dimensions do no maintain a constant ratio to the length of the fish it becomes possible to compare specimens fron different areas only by taking account of variation in length. This has been done by computing mean square regression[1] for each dimension on the fork length or the length of the head. Unfortunately the best fitting regression line is not in all cases a straight line. This difficulty was resolved by Godsil (1948) and Godsil and Greenhood (1951) by using in all cases a regression of the general type :

$$Y = a + bx + \frac{c}{x}$$

Schaefer (1948), Schaefer and Walford (1950), and Schaefer (MS.) chose to simplify the computations by fitting a straight line with a formula of the type,

$$Y = a + bx,$$

but transformed the original data in order to approximate a straight line relationship. This was done by converting either one or both of the measurements to logarithms.

We have followed Schaefer's simpler formula, but even so there remains a great amount of labor. After making the computations for the determination of a regression line for each character on several hundred fish using a standard desk calculator, we found the labor was excessive and approached the International Business Machines Corporation, who worked out a method of doing most of the calculations on their business machines. We provided them with the raw data sheets and, at a cost of about 35 cents per tuna, we received a completely detailed tabulation of the sums, sums of squares, and sums of products of 12 measurements on each of nearly 2,000 tuna. This reduced the time required for handling the basic computations from approximately 10 man-months to 2 man-months.

Throughout our analysis we maintained a very close watch for errors. All computations were duplicated and an overall check of the computations was made for each character from each sample from each area by plotting the individual points and the regression line as computed from the data. Such plotting serves to reveal any divergent observations, any curvilinearity, and any but the most trivial error in the computation. We used the plots to search for divergent observations and omitted from our analysis any which differed more than three standard errors of estimate from the regression line on the assumption that such large discrepancies are errors of observation. The regression line was then recomputed with the aberrant data omitted. If curvilinearity was noticeable and could not be removed by transformation, we dropped the measurements at the ends of the curve and used only fish between 70 and 129.9 cm in length for computing the regression lines and the analysis of covariance. If curvilinearity remained in this central part of the curve, we did not further consider the character.

COMPARISON AND EVALUATION OF DATA

Differences Among Samples

The technique used by all of the authors listed in table 1 has been covariance analysis as described by Snedecor (1946)[2] or in any of several other recent books on statistics. This method uses the basic data as developed through the fitting of the regression lines and it provides a precise answer to the question of whether two samples differ more than would be expected from chance variation. If such a difference exists, it is good proof that the samples were not drawn from a homogeneous population. Schaefer and Walford (1950) and Schaefer (MS.) have shown that the Central American, Angolan (Africa), and Hawaiian populations of yellowfin tuna could not be considered a homogeneous population.

Godsil (1948), using the same technique of covariance analysis, found statistically significant differences among most of his samples from the Central American Region and even between samples taken from the same locality. This suggested to him a fundamental difference in the concepts of statistical and biological homogeneity. Therefore, he developed a measure of divergence which compared the maximum deviation from the average local regression line of a local sample with a deviation of a foreign sample. He summed the deviations for the five characters which he used and arrived at figures showing that the foreign samples (from Japan, Peru, and Hawaii) differed from the local samples much more than the local samples differed among themselves.

Similar statistical studies on other species of fish have shown that there may be statistically significant differences between two populations which are mingling to a considerable extent. Tester (1949)

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[1] These computations follow techniques described by Snedecor (1946).

[2] Our use of statistical terms in this paper follows Snedecor (1946) unless otherwise stated.

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studying the British Columbia herring and Roedel (1952) working with the Pacific mackerel had the opportunity to compare their racial studies with tagging results. Both found statistically significant differences among their samples from areas where the tagging showed considerable intermigration of fish. Therefore, we must conclude that the existence of a statistically significant difference means merely that the populations of fish are not homogeneous, i.e., they are not completely mixing ; they may be partially mixing.

When we compare the yellowfin samples from different areas in all possible ways by means of covariance analysis, we find immediately that statistically highly significant differences result from most comparisons.[1] Using the head length of yellowfin tuna from the 15 areas (table 2) we find that 76 of the 105 possible comparisons result in a variance ratio (F) which is statistically highly significant.[2] Of the remaining 29 comparisons, 13 variance ratios are significant and 16 are not significant. Thus using only a single character we find a majority of comparisons yielding highly significant differences among samples.

Turning to a second character, the distance from the snout to the insertion of the second dorsal, and considering only the samples in which the comparison of head length failed to yield a highly significant difference (table 3), we find that this second character shows a highly significant difference in 14 of the 29 comparisons. Using yet a third character, the distance from the snout to the insertion of the first dorsal, in instances where a highly significant difference was not found with the first two characters considered, we find 3 of the remaining 15 comparisons showing highly significant differences.

We now note that 10 of the remaining 12 comparisons involve areas from which we have our smallest samples: Fiji (13 specimens), Society Is. (33), and Western Caroline Is. (17). With such small samples only relatively large differences can be found to be significant, and even if they are so found the agreement between the sample and the tuna stock in its locality is questionable. However, most comparisons involving these small samples show the same tendency toward significant differences. Eight of the ten comparisons show significant (but not highly significant) differences for one or more of the three characters already considered.

The two comparisons of areas involving larger samples may be extended by considering additional characters. For the Line Island-Palmyra comparison the variance ratio (F) for the distance from the snout to the insertion of the anal is not significant (2.49), but the distance from the snout to the insertion of the ventral shows a highly significant (13.05) value. This is the only highly significant difference found among the five characters considered for these two samples, which are so close geographically.

The other comparison, Eastern *vs.* Central Carolines, yields non-significant F values for the height of the anal (1.22), the height of the second dorsal (1.58), and the greatest body depth (0.09), significant values for the length of the pectoral (3.94), the distance from the insertion of the ventrals to the anterior edge of the vent (4.30), and a highly significant difference in the distance from the snout to the insertion of the ventrals (6.91).

Thus even with samples from the most closely allied stocks, it seems very probable that highly significant statistical differences can be found by increasing the size of the samples, by considering enough characters, or by applying the more critical discriminant function proposed by Fisher (1936). Indeed, our criterion of a highly significant difference is one which would occur from chance variation once in 100 times and in several hundred comparisons we expect to find some such differences due to chance alone. Therefore, we turn from a consideration of the differences among samples to the matter of the relationships among samples.

Relationships Among Samples

It is possible to use the variance ratio (F) to indicate which groups of tuna are most closely related. This requires the assumption that the relationship between the populations is closer when the probability of the observed differences being due to chance increases. Such a comparison is difficult, however, because first the significance of the (F) depends upon the number of observations in the samples, and second the value of (F) is not linearly related to the difference between the samples ; it

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[1] In our analysis of covariance we follow the technique of Kendall, 1948, vol. 2, p. 239, and subtract the deviations from linear regressions within classes from the total deviation from linear regression. This difference is assigned two degrees of freedom and represents a sum of the differences among regressions and the deviations between classes from the mean linear regression.

[2] We shall speak of ratios expected from chance variation less than once in 100 times as highly significant and those expected one to five times per 100 times as significant.

Table 2. Comparison of head length of yellowfin tuna by means of variance ratios (F)

		Equatorial Pacific														
		Costa Rica	120°-130°W. Long.	Line Is.	Palmyra (One of Line Is.)	Phoenix Is.	Marshall Is.	Eastern Caroline Is.	Central Caroline Is.	Western Caroline Is.	Society Is.	Hawaii	Fiji	Japan	Philippine Is.	Angola, Africa
	N	46	43	253	94	120	44	157	208	17	26	203	13	46	353	60
Equatorial Pacific :																
Costa Rica ..	46		14.2	15.0	33.1	22.5	28.6	160.9	116.7	75.6	26.5	9 .2	16.5	31.4	18.2	4.4
Equator at 120°-130°N ..	43			(0.1)	3.3	(1.2)	(1.6)	26.0	18.5	7.2	(0.7)	18.8	0.3	3.5	3.3	6.0
Line Is. ..	253				3.2	5.6	34.3	98.1	38.6	23.6	20.8	106.3	5.2	52.5	24.0	10.2
Palmyra Is. ..	94					(2.3)	48.1	89.4	69.4	23.3	36.2	68.9	0.1	63.7	13.0	18.1
Phoenix Is. ..	120						15.3	43.9	42.7	13.6	8.8	46.9	(1.9)	2 .7	7.8	16.4
Marshall Is. ..	44							9.0	6.0	12.3	(0.6)	7.5	(0.1)	(2.5)	16.4	26.6
Eastern Caroline Is. ..	157								(0.8)	4.3	3.9	4.3	5.9	18.8	89.9	137.5
Central Caroline Is. ..	208									3.1	(2.5)	4.1	7.8	11.4	92.3	112.4
Western Caroline Is. ..	17										7.0	(1.1)	7.2	13.4	32.8	45.0
Society Is. ..	26											4.5	(0.2)	4.3	8.6	21.0
Hawaii ..	203												4.6	7.4	97.3	93.7
Fiji ..	13													(0.7)	2.2	10.2
Japan ..	46														34.6	34.0
Philippine Is. ..	353															12.7

( ) Value expected more than 5 per cent of the time by chance.
——Value expected between 1 and 5 per cent of the time by chance.
All others are expected less than 1 per cent of the time by chance.

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Table 3. Comparison of the distance from snout to insertion of the second dorsal of yellowfin tuna by means of variance ratios. Comparisons are made only in cases showing differences less than highly significant when comparing head length (table 2).

—		Equatorial Pacific														
	N	Costa Rica 46	120°-130°W. Long. 41	Line Is. 254	Palmyra (One of Line Is.) 93	Phoenix Is. 120	Marshall Is. 44	Eastern Caroline Is. 158	Central Caroline Is. 206	Western Caroline Is. 17	Society Is. 31	Hawaii 202	Fiji 13	Japan 46	Philippine Is. 354	Angola, Africa 60
Equatorial Pacific :																
Costa Rica ..	46															3.3
Equator at 120°-130°W. ..	41			10.7	13.6	51.0	15.9				12.5		7.0	20.8	18.4	
Line Is. ..	254				(0.5)											
Palmyra Is. ..	93					4.3										
Phoenix Is. ..	120												(2.2)			
Marshall Is. ..	44										4.6		7.2	6.5		
Eastern Caroline Is. ..	158								(.04)	(0.3)	3.3	19.5				
Central Caroline Is. ..	206									(0.1)	(2.8)	19.0				
Western Caroline Is. ..	17											(2.1)				
Society Is. ..	31											(1.1)	3.3	11.7		
Hawaii ..	202												(2.1)			
Fiji ..	13													4.9	10.0	
Japan ..	46															
Philippine Is. ..	354															
Angola, Africa ..	60															

( ) Value expected more than 5 per cent of the time by chance.
—— Value expected between 1 and 5 per cent of the time by chance.
All others are expected less than 1 per cent of the time by chance.

Table 4. Comparison of the distance from snout to insertion of first dorsal of yellowfin tuna by means of variance ratios. Comparisons are made only in cases showing differences less than highly significant when comparing head length (table 2) or snout to insertion of second dorsal (table 3).

		Equatorial Pacific														
		Costa Rica	120°-130°W. Long.	Line Is.	Palmyra (One of Line Is.)	Phoenix Is.	Marshall Is.	Eastern Caroline Is.	Central Caroline Is.	Western Caroline Is.	Society Is.	Hawaii	Fiji	Japan	Philippine Is.	Angola, Africa
	N	46	43	252	94	118	44	159	208	17	31	201	13	47	353	60
Equatorial Pacific:																
Costa Rica	46															8.8
Equator at 120°-130°W. Long.	43															
Line Is.	252				(2.9)											
Palmyra Is.	94					7.3										
Phoenix Is.	118												$\underline{3.5}$			
Marshall Is.	44										7.0					
Eastern Caroline Is.	159								(0.3)	(2.0)	(0.1)					
Central Caroline Is.	208									(1.3)	(0.1)					
Western Caroline Is.	17											(2.0)				
Society Is.	31											(0.6)	3.9			
Hawaii	201												(1.9)			
Fiji	13													(0.8)		
Japan	47															
Philippine Is.	353															
Angola, Africa	60															

( ) Value expected more than 5 per cent of the time by chance.
—— Value expected between 1 and 5 per cent of the time by chance.
All others are expected less than 1 per cent of the time by chance.

increases much more rapidly than the difference between sample means.

A more satisfactory study of relationships among areas may be made by comparing the dimensions of tuna of a given length. Using the regression formulae which were computed for each character, we have estimated the dimensions of tuna of 100 cm fork length. This length was chosen because it is a round figure and very close to the grand mean of all the yellowfin tuna in our data. Thus it is affected little by fluctuations in the slope of the regression lines.

The estimated values (table 5) on close examination show many significant features. Noteworthy is the tendency for certain samples to show close agreement among all characters. Such is the case between the samples from the Eastern and the Central Caroline Island areas. The greatest difference between areas for any of the nine characters is only 0.5 cm. Almost as close is the agreement between our Line Island sample and Godsil's sample from Palmyra (which is one of the Line Islands). In this case the maximum difference between areas for any of the five characters is 0.7 cm. Much better is the comparison of Schaefer's Costa Rican sample with Godsil's from Panama and Costa Rica. Only four characters may be compared, but the maximum difference is only 0.2 cm. Such figure indicate how close agreement can be, even in th latter two cases where the samples were measure by different people in different years.

A second and most interesting feature of thes data is the tendency for the samples collected alon the Equator in the Pacific to form clines or gradients It will be noted that for the characters head length snout to insertion of first dorsal, snout to insertio of second dorsal, snout to insertion of anal, an greatest body depth, the measurement is greates in the Eastern Pacific and least in the Carolin Island area. A cline in the other direction is indicated for the size of the fins, fish in the Wester Pacific having the largest pectoral, second dorsal and anal fins.

The regularity of these clines can better be appreciated by plotting them against longitude. Thi has been done for head length (figure 2), snout t insertion of second dorsal (figure 3), and length o pectoral (figure 4). It can be seen for each o these characters (and for several others which spac does not permit us to plot here) that the sample from the Equatorial Region do in fact form a clin and that many of the samples from the other region differ quite markedly from the cline. The correlations between the estimated dimensions for th

Table 5. Estimated proportions of yellowfin tuna, 100 cm fork length.

	Head Length	Insertion first dorsal	Insertion second dorsal	Insertion anal	Insertion ventral	Greatest depth	Length pectoral	Height second dorsal	Heigh anal
Angola, Africa	27.2	30.9	52.9	58.2	30.2		28.0		
Pacific Coast of Cent. Am. Panama & Costa Rica	27.5	29.7	52.5	58.7	30.6				
Cocos Island	27.3	29.8	52.5	58.5	30.6				
Galapagos Is.	27.7	30.5	53.0	58.8	30.6				
Clipperton Is.	27.3	30.0	52.7	58.5	30.6				
Gautemala	28.1	30.7	54.1	59.9	31.6				
Mexico	27.8	30.4	53.0	59.2	31.0				
Society	26.4	28.6	51.4				30.2		
Hawaii	25.8	28.8	51.4	56.9	29.2	25.3	29.2	18.4	19.
Fiji	26.4	29.2	51.9	57.2	29.7				
Japan	26.6	29.5	52.2	57.4	29.7	24.7	28.1	18.2	19.
Luzon, P.I.	26.7	29.8	53.4	58.9					
Equatorial Pacific 10°S-10°N Lat.									
Costa Rica	27.3	29.5	52.6	58.9		25.5	27.0	15.8	17.
120°-130° W. L.	26.7	29.7	53.3	58.7	29.3		26.7		
Line Is.	26.9	28.9	51.4	56.9	30.1	24.3	28.7	18.8	20.
Palmyra Is.	26.6	29.2	51.6	56.8	29.4				
Phoenix Is.	26.6	29.2	51.3	56.8	29.8	24.6	29.4	19.8	22.
Marshall Is.	26.5	28.8	51.6	56.7	29.5	24.4	28.9	19.7	21.
Caroline Is.									
Eastern	26.0	28.6	51.0	56.1	29.0	24.1	29.9	21.9	24.
Central	26.0	28.7	51.0	56.5	29.3	24.0	30.2	21.5	23.
Western	25.7	28.8	51.1	56.9	29.1	23.4	29.9	20.7	23.

Note.—Samples obtained as indicated in Table 1.

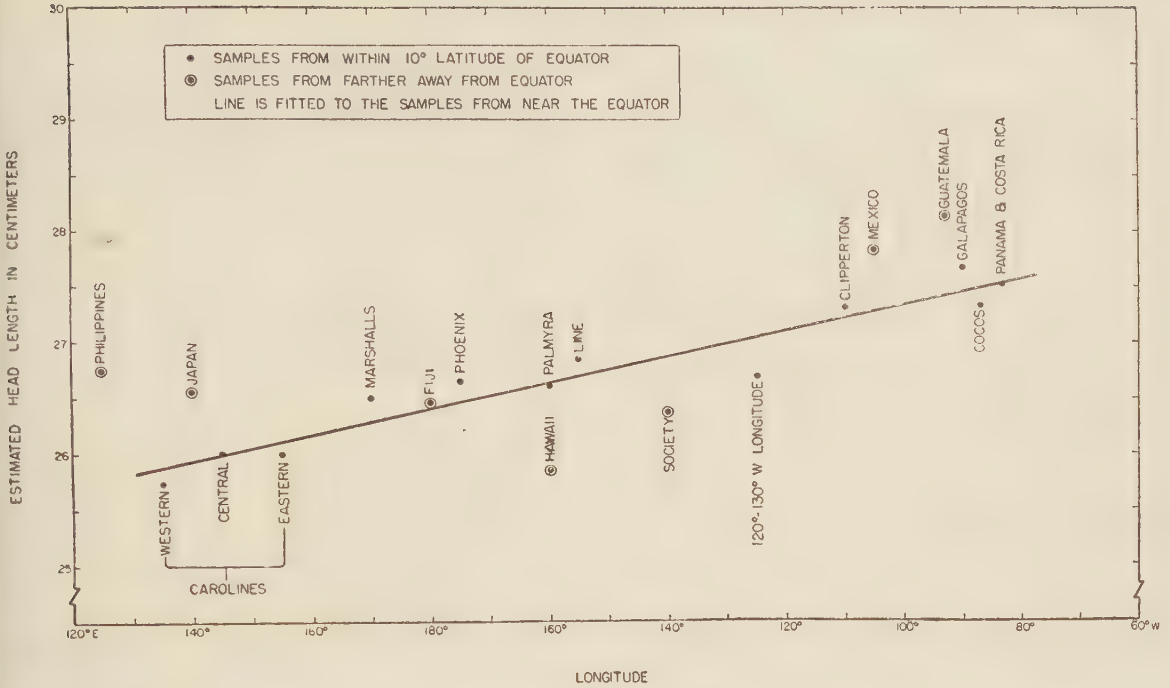

FIG. 2 ESTIMATED MEAN HEAD LENGTH OF YELLOWFIN TUNA 100 CM IN FORK LENGTH

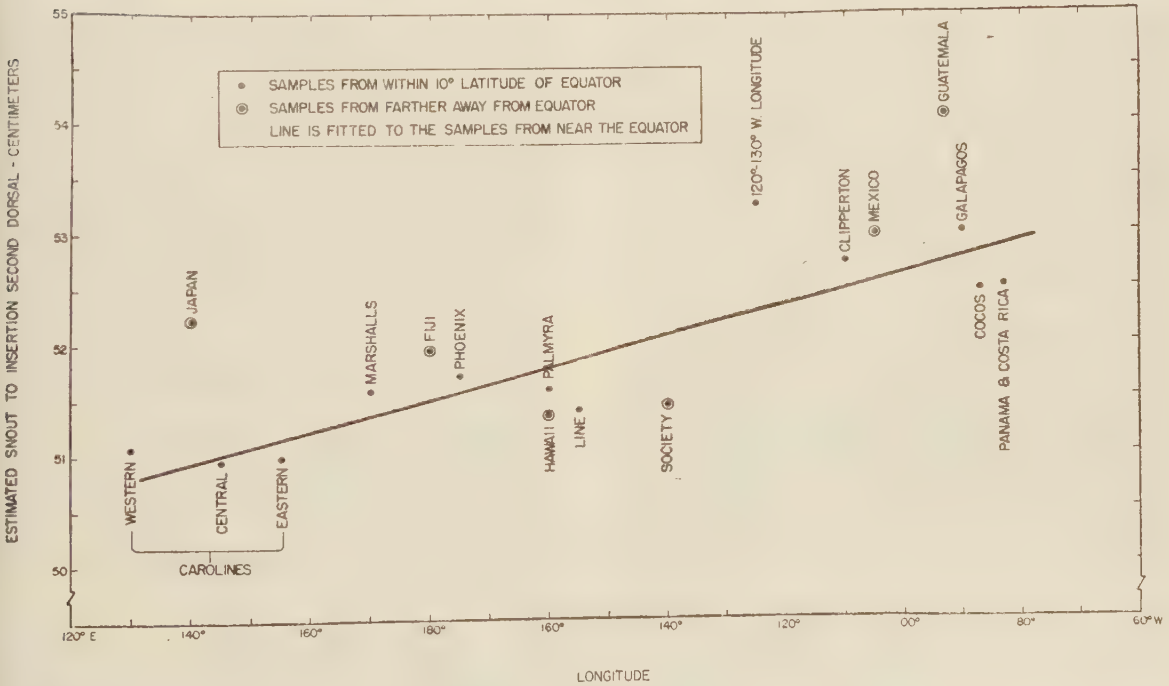

FIG. 3 ESTIMATED MEAN DISTANCE FROM THE SNOUT TO THE INSERTION OF THE SECOND DORSAL OF YELLOWFIN TUNA 100 CM IN FORK LENGTH

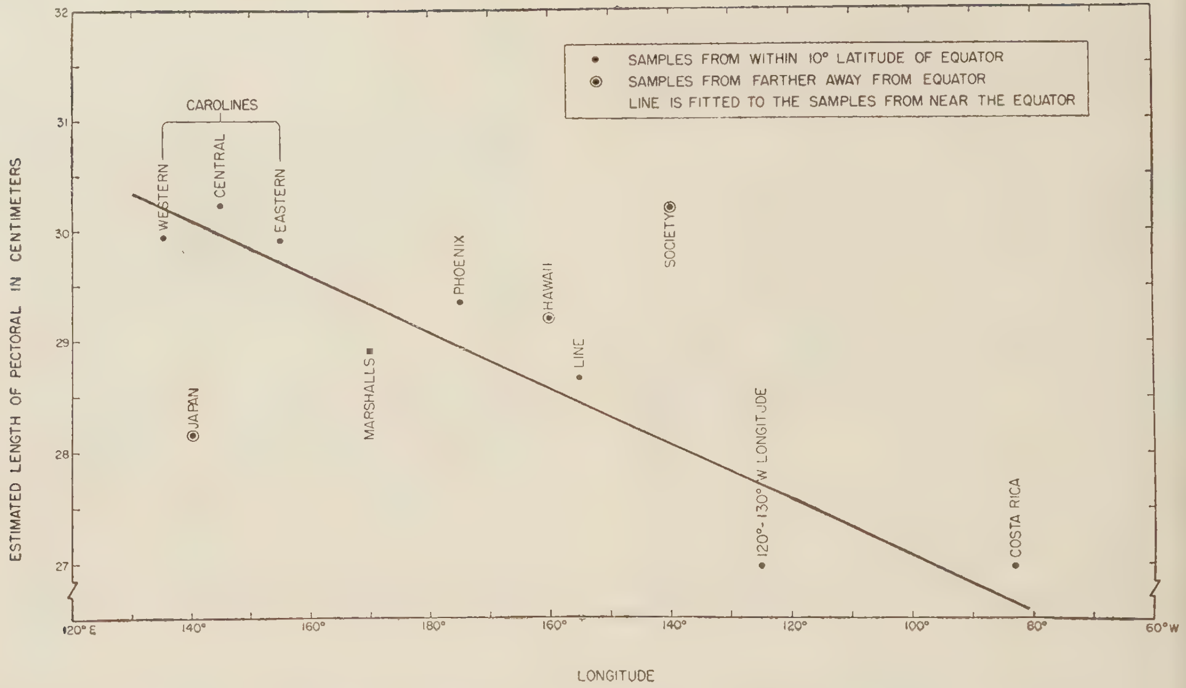

FIG. 4 ESTIMATED MEAN LENGTH OF THE PECTORAL FIN OF YELLOWFIN TUNA OF 100 CM FORK LENGTH

equatorial samples and longitude[1] are statistically highly significant. Head length has a correlation of 0.959 with longitude, the distance from the snout to the second dorsal insertion a correlation of 0.879, and the length of the pectoral a correlation of minus 0.952. Despite these high correlations, the plots of the characters snout to insertion of second dorsal and length of pectoral suggest that the cline is stepped, with breaks between the Caroline and Marshall samples and between the Line Islands and 120°-130° west longitude samples.

Another sample, which was omitted from the above analysis, consists of the three tuna measured in Ceylon by E.R.A. de Zylva. Tuna from this area are of special interest for nomenclatorial reasons and therefore it seems desirable to consider these specimens in spite of their small number. It is not possible to fit a regression line or undertake an analysis of covariance, but we have devised a substitute method of comparing these fish with those from other areas. For each of six characters and for each fish we have taken the actual total length and substituted them in the regression formula a derived for another area. For example, in th first observation in table 6 the actual head length of the Ceylonese tuna differ from the regressio line for head lengths of the Costa Rican tuna by a algebraic total of 0.90 cm. When these values ar totalled regardless of sign for the six characters, w note that the sum is least for the comparison wit the Phoenix Island group and generally low for al of the samples from the central and western Pacific.[2] Markedly higher totals are obtained for th comparisons with Costa Rica and Angola, Africa indicating a more distant relationship.

In order to compare simultaneously all of th characters in our larger samples we turn to a tech nique which has been in use for many years by an thropologists. This is the coefficient of raci likeness which was proposed by Pearson (1926 He suggested the following formula :

$$\text{C.R.L.} = \Sigma \left\{ \frac{1}{M} \left(\frac{(m_s - m_{s1})^2}{\frac{\sigma_s^2}{n} + \frac{\sigma_{s1}^2}{n}} \right) \right\} - 1 + \frac{1}{M} \pm 67449 \sqrt{\frac{2}{M}}$$

---

[1] Longitude was renumbered continuously in an easterly direction from zero.

[2] Comparisons with the Society, Fiji, and Philippine samples have been omitted because all six characters we not measured. Comparison with the sample from near the Equator at 120°-130° west longitude has been omitted becau the latter fish were all much larger than those from Ceylon.

in which m_s = the mean of the sth character of the first group, σ_s the standard deviation, Σ = summation, M = number of characters and n = number of observations. The last term is the probable error. This formula is essentially an average among several characters of the difference between means divided by the standard deviation of the difference.

Other workers soon pointed out that this coefficient of racial likeness varied according to the number of observations and it was standardized for 100 observations by multiplying it by

$$50\left(\frac{\bar{n}_1 + \bar{n}_2}{\bar{n}_1\,\bar{n}_2}\right)$$

Table 6. The algebraic sum of the deviations of the measurements of three yellowfin tuna of Ceylon from the regressions for other areas

	Head Length	Insertion first dorsal	Insertion second dorsal	Insertion anal	Insertion ventral	Length pectoral	Total[1]
Costa Rica ..	-0.90	1.00	-2.80	-5.81	-2.27	5.33	18.11
Line Is. ..	-0.87	0.75	-0.71	-1.08	-1.93	2.38	7.72
Phoenix Is. ..	0.02	1.06	1.22	-0.10	-1.36	0.15	3.91
Marshall Is. ..	1.49	2.94	0.26	-0.19	0.08	0.16	5.12
East Caroline Is. ..	1.98	2.24	0.84	0.72	0.93	-2.26	8.97
Cent. Caroline Is. ..	2.10	1.95	0.93	-0.42	0.23	-3.25	8.88
West Caroline Is. ..	2.71	0.88	0.18	0.08	1.63	-0.60	6.08
Hawaii ..	2.76	2.03	0.44	-1.05	0.77	0.14	7.19
Japan ..	1.79	1.49	-0.70	-0.81	0.39	1.42	6.60
Angola, Africa ..	-1.30	-4.65	-4.85	-5.92	-2.58	5.27	24.57

in which $\bar{n}$ is the mean number of measurements per character for a sample. This became known as the reduced coefficient of racial likeness or R.C.R.L. Most workers also omitted the addition of $\frac{1}{M}$ because of its trivial effect on the total.

Application of this coefficient to our tuna morphometric data requires some further modifications. We are concerned with relative size rather than maximum attained size, and therefore we substitute our mean computed for a given length (in the case of yellowfin it is 100 cm.). We also substitute for the standard deviation the standard error of estimate, which is a measure of the deviation of the points around the line, and we assume that this is the standard deviation which would be obtained if all the tuna measured were of the given length. We also may drop the last term, which was proposed by Pearson as an estimate for the probable error of the coefficient of racial likeness. It is of doubtful validity and our discussion does not require a test of significance among coefficients of racial likeness. Therefore the reduced coefficient of racial likeness as we apply it to our yellowfin tuna data is

$$\text{R.C.R.L.} = 50\left(\frac{\bar{n}_1 + \bar{n}_2}{\bar{n}_1\,\bar{n}_2}\right)\left[\Sigma\left\{\frac{1}{M}\left(\frac{(m_s - m_{s^1})^2}{\frac{\sigma_s^2}{n_s} + \frac{\sigma_{s^1}^2}{n_{s^1}}}\right)\right\} - 1\right]$$

in which m_s is the mean of the sth character estimated for 100 cm total length, σ_s, the standard error of estimate of the regression of the sth character on fork length, n_s the number of observations of the sth character, $\bar{n}$, the mean number of observations of all characters in the first sample and M the number of characters. The symbols s^1 and n_2 refer to the characters in the second sample.

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[1] Without regard to sign.

Summary comparisons for all characters among all our samples have been made as indicated in table 7. It will be seen that the values range from a low of 2.3 to a high of 456.4 The interpretation of these values is facilitated by noting that Pearson (1926), after applying this coefficient to anthropological data, proposed a complicated scale of association. He regarded coefficients of 1 to 13 as showing "association", 13 to 31 as indicating "divergence", and those greater than 31 as indicating "very wide divergence". There is no reason to expect our tuna comparisons to fit the scale proposed for human skull measurements, but the direction is the same, i.e., the smaller values show closer association and the larger values a greater divergence.

Examination of our data discloses that the samples from adjoining localities along the Pacific Equator (figure 1) have coefficients much smaller than average, but there are marked differences among them. The Costa Rican sample compared with the samples at 120° and 130°W. longitude has a coefficient of 14.5 whereas the latter, when compared with the Line Is. sample, has a much larger coefficient of 103.3. The comparisons of Line with Palmyra, Line with Phoenix, and Phoenix with Marshalls are again small, 14.7, 8.9, and 12.1 respectively, but then the Marshalls and Eastern Caroline comparison is 74.2. The Caroline areas seem very closely related, with the Eastern and Central Caroline comparison having a coefficient of only 2.3 and the Central and Western Caroline only 5.0. This substantiates the suggestion that the cline indicated by considering individual measurements is not a smooth one. There appears to be a much greater degree of separation between the Line Islands and 120°-130° west longitude and between the Marshall Islands and Eastern Caroline areas than between any of the other areas.

It should be noted further that most of the Pacific samples obtained some distance from the Equator are not related to other samples as closely as are many of the adjoining samples in the Equatorial area. Comparisons of the Hawaiian samples with other areas show the closest relationship with Phoenix and Central Caroline samples and the most divergence from Costa Rica. The Philippine samples are greatly divergent from the adjoining Caroline Island area and more closely related to the samples from the Eastern Pacific. The Japanese sample is more closely associated with the Fiji, Line Island, and Palmyra samples than with samples from either Costa Rica or the Caroline Island area. An unexpectedly close relationship between Japan and Fiji of only 3.0 was found. We have no explanation for this on the basis of the present data but those samples are very small and it is probably a vagary of sampling.

We also call attention to the comparison of Angola, Africa, with the several areas in the Pacific. These values, while generally high, are not as high as those found when comparing the Costa Rican samples with the Western Pacific samples.

DISCUSSION AND CONCLUSIONS

There are numerous reasons to be skeptical of conclusions based on data of this kind. Foremost perhaps is the fact that racial studies which have shown highly significant statistical differences between stocks have been contradicted by tagging studies. Other reasons for skepticism will occur to people who have had experience with this kind of data and who realize the extreme difficulty of obtaining exactly comparable measurements among different investigators working under greatly different and often trying field conditions.

Both of these factors have been considered and have been the reason for emphasizing the differences and relationships between samples rather than between populations. The comparison is only good if the samples are representative of the areas from which they were obtained. We have made great efforts to obtain large samples and consistent measurements, but we have no way of insuring that they are representative of a population. In fact, if we are to attain a representative sample, we must first describe the population in area and time and it is this very thing that our study is attempting t do.

Schaefer (MS.) has pointed out that better methods of statistical analysis are required. Such methods have been developed and applied by Fisher (1936 and others to racial problems. However, for ou purpose of comparing tunas from widely separate parts of the world it does not seem practical to undertake analyses of greater precision, when such closel allied samples as Godsil's in the Central America area show statistically significant differences whic are difficult of interpretation.

Despite these difficulties there are three feature in our data which give us confidence in them First and most encouraging is the close agreemen between samples collected by different investigator in the same or nearby areas at different time Second, the magnitude of the differences amon some samples seems obviously greater than can b attributed to personal bias. The head length c tuna, which is defined as the distance from the ti of the snout to the most posterior part on the mar gin of the subopercle (depressing the fleshy fla

Table 7. Comparison of yellowfin tuna samples by means of the reduced coefficient of racial likeness

		Equatorial Pacific														
		Costa Rica	120°-130°W. Long.	Line Is.	Palmyra (One of Line Is.)	Phoenix	Marshall Is.	Eastern Caroline Is.	Central Caroline Is.	Western Caroline Is.	Society Is.	Hawaii	Fiji	Japan	Philippine Is.	Angola, Africa
	n[1]	8	9	9	5	9	9	9	9	9	4	9	5	9	5	5
Costa Rica ..	8		14.1	138.0	152.0	[illegible]	235.5	456.4	402.7	389.0	331.9	221.2	117.6	100.5	26.3	75.9
120°-130°W. ..	9			92.4	137.5	145.3	93.0	245.2	205.4	187.0	275.4	115.9	109.8	59.2	12.9	53.3
Line Is. ..	9				14.7	8.9	8.4	64.7	42.6	69.9	54.9	25.9	29.1	28.4	80.4	78.0
Palmyra Is. ..	5					7.3	5.2	57.0	34.9	38.9	22.6	29.2	9.0	31.6	173.5	147.8
Phoenix Is. ..	9						12.1	24.2	15.6	33.4	14.5	15.8	35.4	61.4	125.8	125.8
Marshall Is. ..	9							74.2	59.7	57.0	45.4	34.2	17.1	45.8	300.0	159.5
Eastern Caroline Is. ..	9								2.3	12.1	21.4	25.3	112.4	210.0	339.5	272.3
Central Caroline Is. ..	9									5.0	20.2	17.7	73.5	170.7	185.1	220.2
Western Caroline Is. ..	9										25.4	29.7	52.6	120.7	229.4	288.5
Society Is. ..	4											36.3	35.7	146.1	272.3	326.7
Hawaii ..	9												50.2	68.3	130.3	137.7
Fiji ..	5													3.0	161.7	174.6
Japan ..	9														106.1	68.0
Philippine Is. ..	5															35.0

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[1] Number of characters

extending posteriorly), is a measurement which in our experience can easily be taken consistently by different investigators. The head and opercle are solid structures and the fleshy flap is so flexible that it does not interfere with the calipers. Therefore, there is little reason to expect variation among investigators. Yet the yellowfin tuna from Costa Rica (Schaefer's sample) and from the Western Caroline area show a difference of 1.6 cm in head length for a tuna of 100 cm fork length. The differences in the size of fins are even more marked, being 3.2 cm for the pectoral fin between Costa Rica and the Central Caroline area, 6.1 cm for the second dorsal fin between Costa Rica and the Eastern Carolines, and 7.2 cm for the anal fin between Costa Rica and the Eastern Carolines. Third and last, the gradient between Eastern and Western Pacific in the Equatorial area which exists for almost all characters which were measured by dozens of different investigators cannot possibly be attributed to personal bias. We therefore conclude :

1. Our samples have been taken from stocks which, with the exception of certain adjoining areas in the Equatorial Pacific, are at least semi-independent.

2. The facts that there are greater differences among samples from the Pacific area where the distribution is probably nearly continuous than between Angola, Africa, and any Pacific samples, and the close relationship of specimens from Ceylon to those of the Central Pacific suggest that the yellowfin tuna should be considered as a single species of world-wide distribution.

LITERATURE CITED

Fisher, R. A. (1936).—The use of multiple measurements in taxonomic problems. *Ann. Eugen.*, London 7, pp. 179-188.

Godsil, H. C. (1948).—A preliminary population study of the yellowfin tuna and the albacore. Cali. Div Fish and Game, *Fish. Bull.* No. 70, 90 p.

Godsil, H. C. and R. D. Buyers (1944).—A systematic study of the Pacific tunas. Calif. Div. Fish and Game, *Fish. Bull.* No. 60, 131 p.

Godsil, H. C. and E. C. Greenhood (1951).—A comparison of the populations of yellowfin tuna, *Neothunnus macropterus*, from the Eastern and Central Pacific. Calif. Div. Fish and Game, *Fish. Bull.* No. 82, 33 p.

Kendall M. G. (1948).—The advanced theory of statistics. Vol. 2, London, 521 p.

Marr, J. C. and M. B. Schaefer (1949).—Definitions of body dimensions used in describing tunas. U.S. Fish and Wildlife Service, *Fish. Bull.* No. 47, Vol. 51, pp. 241-244.

Pearson, Karl (1926).—On the coefficient of racial likeness. *Biometrika*, Vol. 18, pp. 105-117.

Roedel, Phil. M. (1952).—A racial study of the Pacific mackerel, *Pneumatophorus diego.* Calif. Div. Fish and Game, *Fish. Bull.* No. 84, 53 p.

Schaefer, M. B. (1948).—Morphometric characteristics and relative growth of yellowfin tunas (*Neothunnus macropterus*) from Central America. *Pacific Science*, Vol. 2, No. 2, pp. 114-120.

Schaefer, M. B. (in press)
Racial characteristics of the yellowfin tuna (*Neothunnus macropterus*) from the Hawaiian Islands and comparison with those of the American west coast.

Schaefer, M. B. and Lionel A. Walford (1950).—Biometric comparison between yellowfin tunas (*Neothunnus*) of Angola and of the Pacific coast of Central America. U.S. Fish and Wildlife Service, *Fish. Bull.* No. 56, Vol. 51, pp. 425-443.

Snedecor, G. W. (1946).—Statistical methods. Ames, Iowa, 485 p.

Tester, A. L. (1949).—Populations of herring along the west coast of Vancouver Island on the basis of mean vertebral number, with a critique of the method. Canada Fish. Res. Bd. *J.* Vol. 7, No. 7, pp. 403-420.

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NOTES ON GULF OF MAINE FISHES IN 1952.—The following observations were made during the Atlantic herring investigation sponsored by the Maine Sardine Packers Association, Maine Department of Sea and Shore Fisheries, Maine Sardine Industry, and the U. S. Fish and Wildlife Service.

Etrumeus sadina (Mitchill); Atlantic round herring.—During August and September, 1952, the Atlantic round herring was a common fish in Maine waters. This species rarely strays north and east of Cape Cod (Bigelow and Welsh, 1925, Bull. U. S. Bur. Fish., 40 (1): 92). It has not been possible yet to obtain data on the exact quantities of round herring caught in Maine; however, I estimate that at least 3,000 bushels (210,000 pounds) were landed. Some specimens of this species were mixed with Atlantic herring (*Clupea harengus*) and taken to sardine canneries. The greatest quantities were used for lobster bait or fish meal. For a chronological account of the 1952 appearance of this species on the Maine coast, see Scattergood (1952, Maine Coast Fisherman, 7 (2): 8). Most of the fish were caught around the Mount Desert Island–Swans Island area. A sample of 32 fish ranged in length from 138 to 157 mm., with a mean length of 145. 8 mm. The copepod, *Calanus finmarchicus* (Gunnerus), was present in most of the stomachs.

Sarda sarda (Bloch); Atlantic bonito.—During June 1952, a 219-mm. bonito was caught in a mackerel gillnet in Boothbay Harbor, Maine, and on Sept. 27, 1952, a 359-mm. specimen was taken in a herring stop seine at Southport Island, Maine.

Coryphaena hippurus Linnaeus; dolphin.—When a sportsfisherman in Peeble's Cove, Cape Elizabeth, Maine, noticed a fish swimming near the surface, he carefully maneuvered his boat and drove the fish into shallow water where he was able to capture it with his hands. The specimen was a 944-mm. dolphin. In recent years dolphins have been reported from Cape Cod and Nova Scotia (Schuck, 1951, COPEIA (1): 171), but this is the first record in Maine waters.

Zenopsis ocellatus (Storer); John Dory.—During the last week of May, 1952, the otter trawler, THERESA R., while fishing for groundfish, caught a 201-mm. John Dory in 75 to 85 fathoms of water 18 to 20 miles east of Mount Desert Rock, Maine. The specimen was presented to us by Captain Reuben S. Doughty and Harold Paulson of Portland.

Urophycis tenuis (Mitchill); mud hake.—On February 1, 1952, I examined 100 mud hake at Wilson's Beach, Campobello Island, New Brunswick, and found 2 specimens exceeding the maximum size previously reported (Scattergood, 1952, COPEIA (3): 206). One was 53 inches long and weighed 47¼ pounds; the other was 52 inches and 46 pounds. The fish were caught by line trawlers off Beaver Harbor, N. B., in the Bay of Fundy. (The name white hake is used by the U. S. Fish and Wildlife Service for this species, and is preferred by the author.)

Paralichthys dentatus (Linnaeus); summer flounder.—On June 8, 1952, Robert W. Davis of the Maine Department of Sea and Shore Fisheries caught a 411-mm. summer flounder in a fyke net set in 4 fathoms of water at Boothbay Harbor, Maine. This was an unusual capture, for Ginsburg (1952, U. S. Fish and Wildl. Serv., Fish. Bull. 71: 318) reported that, according to the data extant, the summer flounder does not occur north of Cape Cod.—LESLIE W. SCATTERGOOD, *U. S. Fish and Wildlife Service, Boothbay Harbor, Maine.*

NOTES ON THE ABILITY OF THE HORSESHOE CRAB, *LIMULUS POLYPHEMUS*, TO LOCATE SOFT-SHELL CLAMS, *MYA ARENARIA*

By

Osgood R. Smith

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NOTES ON THE ABILITY OF THE HORSESHOE CRAB, *LIMULUS POLYPHEMUS*, TO LOCATE SOFT-SHELL CLAMS, *MYA ARENARIA*

One of the important items in the food of the horseshoe crab, *Limulus polyphemus*, in New England is the commercially important soft-shell clam, *Mya arenaria*. Hence, the habits of the horseshoe crab are of interest to shellfish biologists.

The predaceous activities of the horseshoe crab have been reported by Turner *et al.* (1949) and observed by the author during the course of various clam transplanting experiments in Plum Island Sound, near Newburyport, Massachusetts. An outstanding exhibition of clam destruction by horseshoe crabs occurred during the summer of 1949. On May 26 and June 2, 16 bushels of clams, averaging 39 mm. in length, were planted in six plots on a flat composed of moderately soft sandy mud and in five plots on a nearby flat of firm sand, bonded with fine silt and shell fragments. Native clams (*Mya*) were scarce on both flats. The round clam, *Macoma baltica*, and the little gem shell, *Gemma gemma*, which also are eaten by horseshoe crabs, were common but the plots still presented an artificial concentration of food for the horseshoe crabs. The planted clams dug in well judging by counts of holes the day after planting. Within a week, however, the horseshoe crabs were swarming over the plots. On June 7, 31 of them were found in three 10 x 20-foot plots on the sandy flat. On the muddy flat the entire surface of the planted area was so thoroughly excavated that square pools of water marked the plots at low tide. When these plots were dug in November, 92 percent of the clams had disappeared.

The concentration of horseshoe crabs on the plots of clams might have been due solely to random movements if during the course of such wandering they found food and stayed to eat. However, we believe that horseshoe crabs do not dig entirely at random and that they can locate clams at least two or three feet away. Field evidence that such is the case presented itself on June 21, 1951, in the form of tracks left by one horseshoe crab over a series of small plots of clams.

As part of a race and growth experiment, clams had been planted in small plots or groups of fifty in a grid pattern. Each group of fifty occupied a circle about 18 inches in diameter, and the groups were arranged in three rows of 12 groups each, all three feet apart. Chicken wire with one-inch meshes had been staked down over the entire area to protect the clams. When the horseshoe crab tracks were seen, much of the chicken wire had been buried about a half-inch by a layer of fine silt which showed the tracks perfectly.

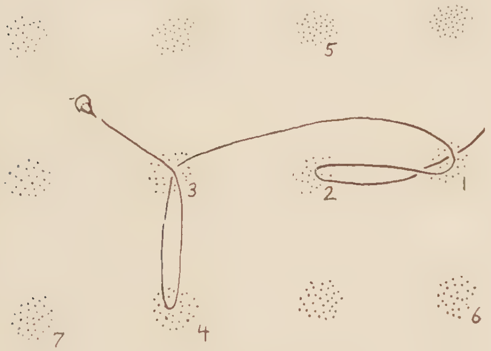

Fig. 1. Diagram of horseshoe crab tracks over 12 plots of soft-shell clams, June 21, 1951. There were crab excavations at all 7 numbered plots, but none at the 29 remaining plots included in the race-growth experiment.

Referring to the diagram (Fig. 1), it may be seen that the tracks started at plot No. 1, then went to 2, then back to 1, then across to 3, down to 4, back up to 3, and then a little beyond 3 where the horseshoe crab was found. If we count the plots visited twice, the crab was "on his target" six times. There was an excavation in the surface mud at each plot visited, exposing the wire underneath and extending below the wire in spots where the horseshoe crab had been trying to dig through the meshes. In addition, there were older water-worn depressions over plots 5, 6 and 7, but no tracks. There were no depressions over the other plots of clams or between the plots, the mud covering the wire in an even sheet except for the small clusters of clam holes extending up through the wire and mud. Therefore, the horseshoe crab did not dig where there were no clams, as might be expected if digging were entirely random. The route of the tracks from plot 1 to 3 is not the shortest route to the nearest clams, but the general pattern of the tracks, plus the fact there were no misses, strongly suggests an ability to locate clams. The two cases where he doubled back to visit plots a second time might indicate a sort of memory.

Reference

Turner, Harry J., Jr., John C. Ayers and Charles L. Wheeler. 1948. The horseshoe crab and boring snail as factors limiting the abundance of the soft-shell clams. Report on investigations of the propagation of the softshell clam, *Mya arenaria*. Mass Div. of Marine Fisheries Dec. 31, 1948. Appendix II, pp. 43-45.

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OBSERVATIONS ON THE RATE OR DECAY OF SOFT-SHELL CLAMS (*MYA ARENARIA*)

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OBSERVATIONS ON THE RATE OF DECAY OF SOFT-SHELL CLAMS (*MYA ARENARIA*)

Some knowledge of the length of time it takes a clam to disintegrate after death is necessary in order properly to analyze field mortality data. For instance, a certain proportion of clams dug may be in various stages of decay, from a relatively firm visceral mass to merely two shells full of evil smelling water. Both of these might be termed "recent," but does "recent" mean a few days, several weeks, or a month or more?

In order to make some approximations of the rates of decay, dead or freshly killed clams were buried in the clam flats of Plum Island Sound, Newburyport, Massachusetts, and dug up at intervals. One batch of clams that had died in the laboratory was buried on January

TABLE I. *The rate of decay of clams in clam flats of Plum Island Sound, Massachusetts—1950*

Date	Number of Days Buried	Condition of Clams
WINTER		
Horseshoe Flat — Hard firm sand, some fine silt.		
January 16	0	Buried dead clams.
April 10	84	Full of soft runny meat.
May 5	109	Full of very soft meat, relatively firm at base of siphon.
SUMMER		
Hales Cove — Moderately soft mud.		
June 13	0	Clams killed and buried.
June 21	8	Relatively firm, not runny, very smelly.
July 18	35	Traces of rotten meat, some mud, very smelly.
Horseshoe Flat — Hard firm sand, some fine silt.		
June 19	0	Killed and buried 1-½ and 2-½ inch clams.
July 5	16	All rotten, but full of meat.
July 10	21	Larger clams full of soft rotten meat. Small clams with traces of decayed meat.
August 30	72	Larger clams nearly empty but with mass of cheese-like brown rotted meat. Small clams empty but with mantle periostracum intact, shell not fully clean, no soil between shells.

16, 1950. Other clams were killed by stabbing them between the shells and twisting the knife, and buried on June 13 and 19, 1950. Periodically, four to six clams were dug from each planting and examined for extent of decay. The results are given in Table I.

The visceral mass disintegrated very slowly during cold weather. In winter and spring, meats were still present within the shells, although partially decayed, after the clams had been buried 109 days. In summer, the meats were even more decayed after only 21 or 35 days.

The size of the clams also affects the period needed for complete decay. Larger clams averaging 2-½ inches in length buried at Horseshoe Flat during June retained meat within the shells for a longer period than did the 1-½-inch clams. Even after 72 days, some cheese-like brown rotted meat remained in the larger shells, while small ones were nearly clean.

The slow rate of decay or disappearance of the meats probably is associated with anaerobic conditions in the flats as well as an absence of scavengers. The oxygen content of the soil was not determined, but general observations indicate that anaerobic conditions prevail. Plant detritus embedded with the silt is usually black or dark brown. Pieces of iron that have rusted away above the soil show very little rust below, and chicken wire fencing which rusts in a summer in sea water will remain strong and bright where buried six inches in the mud.

As might be expected, there was some variability in the rate at which shells fill with soil after the animals decay. In the firm sand of Horseshoe Flat, the shells did not contain soil even after being in the flat 72 days, while in the softer mud of Hales Cove the soil had started to work into shells after 35 days. In other experiments in which live clams were transplanted in April we have found shells completely full of mud two months after they were planted. The date of death is not known in such cases, but obviously the animals decayed and their shells filled with mud in something less than two months.

Table I shows that decaying or nearly disintegrated clams found in the spring may have died during the winter or even the previous fall. Similar clams found in late summer might have been dead one or two months when found. Mortality records should therefore be corrected for the slow rate of decay of buried dead clams.

These observations also suggest the possibility that "mass mortalities" reported at various times may actually have occurred over a period of several months instead of all at one time as often supposed.

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ANTIBIOTIC TREATMENT OF ULCER DISEASE AND FURUNCULOSIS IN TROUT

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Introduction

Ulcer disease and furunculosis are two of the most dreaded bacterial diseases of salmonid fishes. The etiological agent of furunculosis (*Bacterium salmonicida*) was first recognized by Emmerich and Weibel in 1894. However, a satisfactory method of treating this disease was not developed until recently when Gutsell (1948) introduced the very effective sulfamerazine therapy.

In contrast to furunculosis of fish, the etiology of ulcer disease was not recognized until very recently. Calkins (1899) assumed that ulcer disease was caused by a sporozoan parasite, *Lymphosporidium truttae*. According to Hofer (1904), the disease was caused by bacteria which could be seen in the lesion; however, he was not able to isolate and cultivate the microorganisms. Studies concerning the pathology, mode of transmission, and therapy of this disease have been carried out by Marsh (1905), Fish (1934), Wolf (1939, 1941, 1947), and Tunison and McCay (1937). The question of the etiology of the type of ulcer disease, which is also called "red spot," remained unsolved until Snieszko and Friddle (1950) and Snieszko, Griffin, and Friddle (1950) isolated and described *Hemophilus piscium*. This microorganism has been found in all of those outbreaks of ulcer disease in brook trout (*Salvelinus fontinalis*) which have been investigated and which have occurred during the last 4 years in the northeastern section of the United States. Reed and Toner (1942) described another type of ulcer disease in Canada and isolated *Pseudomonas hydrophila* from the diseased fish and from the water in which these fish were found. Still another type of ulcer disease was recently described by Flakas (1950) who isolated a Gram positive bacillus from diseased brook trout in Wisconsin.

These various reports on fish diseases which are characterized by one common symptom, viz., the appearance of external ulcerations, indicate that the term "ulcer disease" is a general one. Protozoans like *Lymphosporidium truttae,* bacteria like *Ps. hydrophila, H. piscium,* unidentified gram positive bacilli, and perhaps other microorganisms can cause external ulcerations in fishes. Only further and thorough study of the pathology and etiology of any of the infectious and noninfectious ulcerative fish diseases will permit the differentiation of diseases belonging to this group. In this paper, the term "ulcer disease" will be restricted to a fish disease caused by *Hemophilus piscium* with symptoms and pathology as described in detail by Fish (1934) and Wolf (1939).

The early attempts to treat ulcer disease with various disinfectants and drugs (including sulfonamides) were usually unsuccessful (Tunison and McCay, 1937; Wolf, 1939, 1941, 1947). The observations made at the Leetown station also indicated that treating ulcer disease with sulfamerazine was ineffective. The first promising results (Snieszko, Friddle, and Griffin, 1951) were obained with a new antibiotic, terramycin. Therefore, it seemed of interest to investigate the problem on a more extensive scale.

Since the trout under investigation suffered from a mixed infection with both *B. salmonicida* and *H. piscium* in the initial experiments and in one reported in this paper, it was considered advisable to start an artificial epizootic caused by only one of these pathogens at a time. Only by such a procedure was it possible to determine the therapeutic value of the antibiotics used in the experimental treatment of either ulcer disease or furunculosis.

METHODS

The experiments described in the present report were performed on fingerling and adult brook trout (*Salvelinus fontinalis*). Terramycin, aureomycin, and chloramphenicol were selected from the many known antibiotics (Baron, 1950) for these experiments. These three antibiotics are generally effective in the treatment of diseases which are caused by Gram negative bacteria and both terramycin[1] and aureomycin[1] are available in a crude and therefore less expensive form. This last consideration was prompted by the recognition of the economic factor which is so important in the selection of drugs to be used for the treatment of fish diseases. Chloramphenicol was used because both *H. piscium* and *B. salmonicida* were highly sensitive to this antibiotic when tested *in vitro.* It may be of interest to note that chloramphenicol was also shown to be of value in the control of red leg in frogs (Smith, 1950).

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[1] Several crude forms of terramycin were generously provided by Chas. Pfizer and Co., Brooklyn, N. Y., and two forms of crude aureomycin were also supplied by Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.

The antibiotics were given orally by mixing them with regular trout food which was composed of equal parts of ground beef spleens and dry mix. The dry mix was made of fish meal, wheat middlings, cottonseed meal, and salt in a ratio of 50, 25, 25 and 4 parts, respectively. The various dosages used in these experiments were expressed in terms of the pure antibiotic. For instance, ''aurofac,'' one of the crude forms of aureomycin, contained, according to the manufacturers, 1 gram of aureomycin hydrochloride per 250 grams of substance. ''Crude aureomycin'' contained 10 per cent of aureomycin hydrochloride. Terramycin was used either as the crystalline hydrochloride or as ''terracon 180.'' The latter contained 1 gram of terramycin hydrochloride in 2.5 grams of substance. Chloramphenicol was used only in the pure crystalline form. All of the antibiotics tested were evenly distributed in the dry mix which subsequently was mixed with ground beef spleens. After all of the components of the diet were weighed and distributed into portions based on a feeding rate equated to the size and the age of fish employed (Duell, 1942), a quantity of water was added to adjust the diet to a uniform consistency. All fingerling fish were fed twice each day except during the weekend when the entire day's ration was given in one feeding. The average temperature of the water was approximately 12 to 13° C.

RESULTS

The first experiment was carried out with adult brook trout,[2] the average weight of which was about 180 grams. Bacteriological examination of a few trout with typical ulcers selected from a population of several thousand, revealed only the presence of *H. piscium.* From this large population about 500 trout were so selected that approximately 50 per cent of them had typical ulcers. It was noted that the mortality rate was low at the start of the experiment. These trout were distributed in even quantities among 12 troughs. Trout in four troughs were treated with chloramphenicol, another four were treated with pure terramycin, and the remaining four troughs served as the untreated controls; treatments were randomized. Chloramphenicol and terramycin were mixed with the food in the manner described and given at a rate of 50 milligrams per kilogram of fish per day. The food containing the particular antibiotic was given once daily at a rate of 2 per cent of the weight of trout.

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[2] The fish and drugs used in this particular experiment were kindly supplied by the Maryland Game and Inland Fish Commission.

The data in Table 1 indicate that both chloramphenicol and terramycin were about equally effective in stopping the mortalities after 10 days. During the remaining 10 days of treatment, two trout died among those which had been treated with terramycin. *B. salmonicida* and *H. piscium* were isolated from fish which died on February 1 and only *B. salmonicida* was found in another which died on February 5. Of the control trout which died between January 31 and February 10, *H. piscium* was isolated from four fish and *B. salmonicida* from 17 fish. This suggested that more of the trout suffered from furunculosis than from ulcer disease.

On the 10th of February all of the fish from each group which had received treatment were mixed and again redistributed equally on a weight basis among the same troughs used at the outset of these experiments. Each group (including the controls) was divided in two smaller groups of two troughs each (Table 1). The fish in two troughs of each of these subgroups received further treatment, the remaining two troughs were maintained without additional treatment. One-half of the former control group (which survived the infection during the first stage of the experiment) received treatment with 50 milligrams of terramycin and 200 milligrams of sulfamerazine (9 grams per 100 pounds) per kilogram of trout per day. In this phase of the experiment, there were only a few mortalities in those trout which had been treated in the first phase of the experiment or continuously with terramycin and chloramphenicol (Table 1). The mortalities were somewhat increased among those fish which were treated with terramycin but the difference was too small to be significant. In the trout which received terramycin and sulfamerazine combined from February 11 to 28, the mortality rate rapidly decreased. The latter reflects the effectiveness of this type of treatment when used against mixed infections involving both *B. salmonicida* and *H. piscium*.

At the end of the experiment (Table 2), all of the remaining trout were examined for the presence of open ulcers, healed ulcers and scars. The data in Table 2 indicate that among those trout treated with terramycin or chloramphenicol, very few showed evidence of open or partially healed ulcers. In the group treated with terramycin and sulfamerazine there were 25 per cent with unhealed ulcers. In the control trout there were 65 per cent with unhealed ulcers. Those trout which still had open or partly healed lesions at the end of the experiment were examined biologically on March 1 and 2. Of the four

TABLE 1. TREATMENT OF ADULT BROOK TROUT (*SALVELINUS FONTINALIS*) WITH CHLORAMPHENICOL AND TERRAMYCIN

Items	Chloramphenicol				Terramycin Replicates				Controls			
	A	B	C	D	A	B	C	D	A	B	C	D
Number of trout at the start	44	44	44	44	44	44	44	44	44	44	44	44
Weight of trout per trough in kilograms	8.0	8.2	8.2	8.2	8.3	8.2	8.2	8.3	8.1	8.1	8.2	8.2
Number mortalities per period 1/21 to 1/25/51	4	..	1	4	..	..	2	1	4	..	..	2
" " " " 1/26 to 1/30/51	..	..	1	2	2	1	3	1	4	..	1	2
" " " " 1/31 to 2/4/51	..	..	..	..	..	..	1	..	..	3	2	3
" " " " 2/5 to 2/10/51	..	..	..	..	..	..	..	1	4	5	5	3
Total number and per cent mortalities	12-6.8%				12-6.8%				38-21.6%			
Rearrangement of treatments	Chloram-phenicol		No treatment		Terramycin		No treatment		Terramycin & Sulfamerazine		Controls	
Number of trout on start 2/11/15	42	39	41	39	41	40	39	40	36	34	36	38
Number mortalities per period 2/11 to 2/15/51	..	..	..	..	..	..	..	1	2	3	7	5
" " " " 2/16 to 2/20/51	..	1	..	..	1	..	..	..	4	1	2	5
" " " " 2/21 to 2/25/51	..	..	..	..	..	..	..	..	..	1	2	5
" " " " 2/26 to 2/28/51	..	..	..	..	..	..	1	..	..	1	1	3
Total number and per cent mortalities	1 = 1.2%		.. ..		1 = 1.2%		2 = 2.5%		12 = 17%		30 = 40%	

Water temperature 54° F.

trout with lesions taken from the group which had been treated with chloramphenicol, neither *B. salmonicida* nor *H. piscium* was isolated; however, *B. salmonicida* was isolated from the lesions of two out of three trout which were taken from the terramycin-treated group. *H. piscium,* but not *B. salmonicida,* was isolated from the lesions of two trout which had been treated with terramycin and sulfamerazine during the second phase of the experiment. Of the six dead trout which did not receive treatment during the course of the entire experiment (control group), *H. piscium* was isolated from the kidney of one fish and *B. salmonicida* was isolated from the kidneys of three fish. No bacteria were found in the partly healed ulcers of the two remaining trout of this group.

TABLE 2. TREATMENT OF ADULT BROOK TROUT (*SALVELINUS FONTINALIS*) WITH CHLORAMPHENICOL AND TERRAMYCIN. RESULTS OF THE EXAMINATION OF THE SURVIVING TROUT FOR THE PRESENCE OF ULCERS, OPEN LESIONS, AND SCARS AT THE END OF THE EXPERIMENT

Treatment	No visible lesions or scars (per cent)	Healed ulcers, scars only (per cent)	Open ulcers or lesions (per cent)
Chloramphenicol 1/21 to 2/28/51	47	49.5	3.7
" 1/21 to 2/10/51	47	52	1.3
Terramycin 1/21 to 2/28/51	51	49	0
" 1/21 to 2/10/51	40	55	5.5
Controls followed by terramycin and sulfamerazine	29	45	25
Controls	27	8	65

Another experiment was carried out with fingerling brook trout during the summer of 1951. These trout were treated with terramycin (terracon 180) and aureomycin (aurofac and crude aureomycin). The treatments began in the middle of May and the antibiotics were added to the food in quantities calculated at a rate of 25 to 28 milligrams of antibiotic per kilogram of fish per day. Another lot of the same trout was fed with commercial pelleted fish food in a manner recommended by the manufacturer. The pellets were reputed to be fortified with a certain antibiotic for the purpose of promoting better growth in fish. Data as to the exact nature and quantity of antibiotic(s) used in the manufacture of these pellets were not available to the authors. These pellets were fed in order to test their possible prophylactic value against furunculosis or ulcer disease. The control fish were fed the regular diet previously mentioned.

During the first part of the experiment, the trout were maintained in 12 circular pools. Since there were no natural outbreaks of furunculosis or ulcer disease until the middle of June, artificial infections were initiated. For this purpose two kilogram lots of trout taken from each pool were distributed into experimental troughs (Tables 3

TABLE 3. TREATMENT OF ULCER DISEASE. MORTALITIES, PER PERIODS, OF FINGERLING BROOK TROUT. DAILY DOSAGE OF TERRAMYCIN OR AUREOMYCIN PER KILOGRAM OF FISH WAS 25 MILLIGRAMS UP TO THIRTEENTH LAPSED DAY, 50 MILLIGRAMS UP TO TWENTY-SEVENTH LAPSED DAY, AND 75 MILLIGRAMS TO THE END OF THE EXPERIMENT. ON JUNE 19 FISH WERE DISTRIBUTED AT A RATE OF 2 KILOGRAMS PER TROUGH. TEMPERATURE OF WATER 13° C.

Items	Terramycin			Average per cent per day	Aureomycin		Average per cent per day	Controls		Average per cent per day
	Replicates A	B	C		Replicates A	B		Replicates A	B	
No. of trout at start, 6/19/51	243	407	264		181	217		227	206	
No. of fish inoculated out of total, 6/21	12	12	12		12	12		12	12	
Mortalities:										
during incubatory period to 6/27	8	12	10		10	10		9	10	
lapsed days 1-8 from 6/28	1	9		0.1		1	0.03	1		.03
" " 9-13	1	4	3	0.2	2	2	0.2	1	1	.1
" " 14-18	1	21	4	0.5	4	4	0.4	7	1	.4
" " 19-23	8	14	5	0.5	20	19	2.1	21	5	1.3
" " 24-28	2	12		0.3	51	47	6.2	56	15	3.8
" " 29-33		5	3	0.2	59	53	10.2	65	30	6.7
" " 34-38	1	5	3	0.2	21	51	12.3	35	44	8.6
" " 39-43		5	1	0.1	8	24	13.7	24	48	13.5
" " 44-47	1	7	0	0.2	5	3	16.7	0	22	4.5
Mortalities total, No.	23	94	29		180	214		219	176	
Mortalities total, per cent	9.5	23	11		99	99		99	87	
No. of fish unaccounted for	3	16	11			2		5	3	

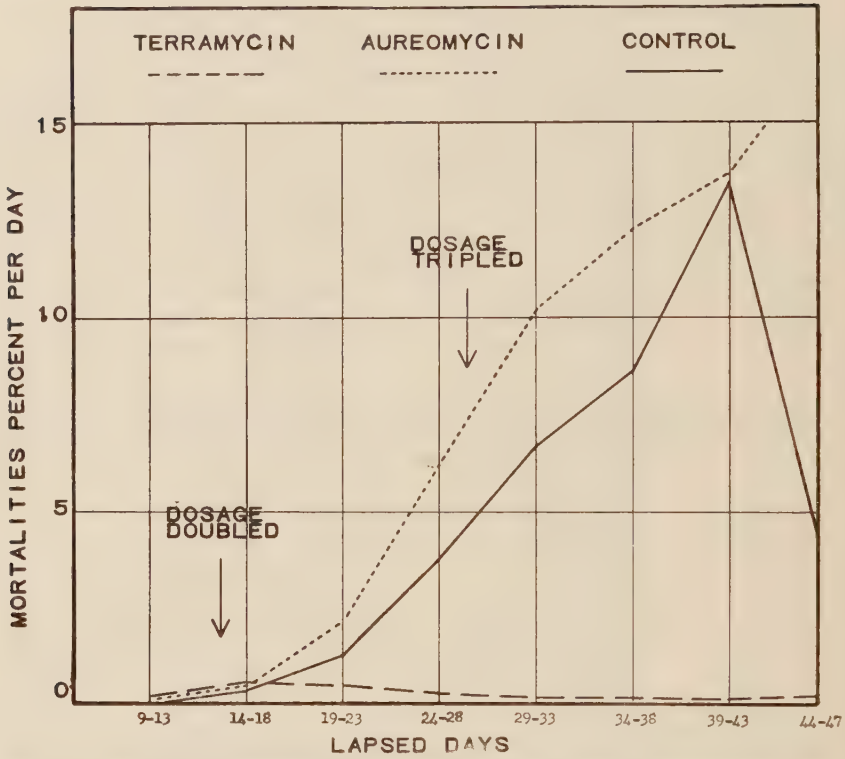

Figure 1. Ulcer disease. Mortalities of fingerling brook trout treated with antibiotics. Starting dosage 25 milligrams per kilogram of fish per day.

and 4). Those trout given aureomycin received "crude aureomycin" from the time they were transferred to the experimental troughs. One group of the fish was infected with *B. salmonicida* and the other with *H. piscium.* The infections were started by the parenteral inoculation of 10 to 12 fish with microorganisms taken from a culture of *H. piscium.* The other group was inoculated with *B. salmonicida.* The inoculated fish soon evidenced symptoms of acute furunculosis or ulcer disease depending upon the organism used as the infecting agent. The uninoculated fish which developed infections due to contact with the inoculated trout showed typical signs of either ulcer disease or furunculosis.

It is evident from Tables 3 and 4, and Figures 1 and 2, that the dosage of 25 milligrams of aureomycin or terramycin per kilogram of fish per day was not sufficient to prevent the spread of infection and the increase of mortalities. Therefore, on the fourteenth lapsed day the dose was doubled. This resulted in a satisfactory response. On the twenty-sixth or twenty-seventh lapsed day the dose was increased to 75 milligrams without any apparent additional advantage (Figures 1 and 2). Of the two antibiotics tested, only terramycin was of therapeutic value in the treatment of both diseases. The losses were somewhat larger among those fish infected with *B. salmonicida,* but this may have been due, in part, to the usually faster progress of furunculosis; consequently, higher losses would be expected during the first period of the test at which time the antibiotic levels were only 25 milligrams per kilogram of trout per day. Aureomycin had no effect

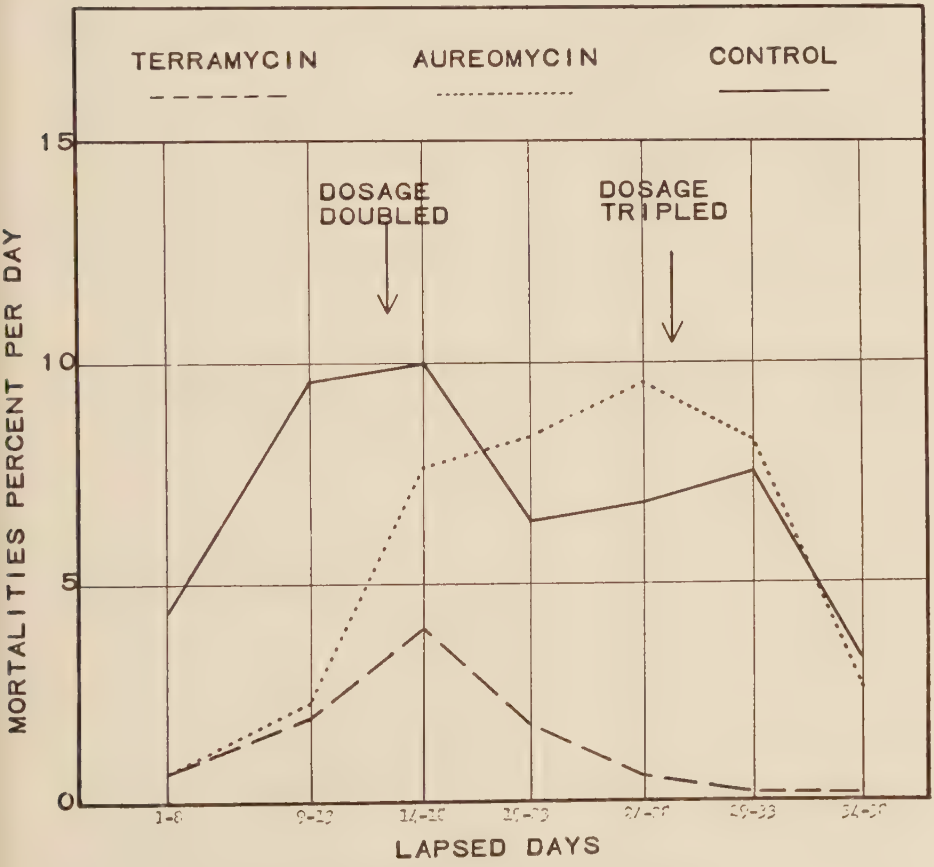

Figure 2. Furunculosis. Mortalities of fingerling brook trout treated with antibiotics. Starting dosage 25 milligrams per kilogram of fish per day.

TABLE 4. TREATMENT OF FURUNCULOSIS. MORTALITIES, PER PERIODS, OF FINGERLING BROOK TROUT. DAILY DOSAGE OF TERRAMYCIN OR AUREOMYCIN PER KILOGRAM OF FISH WAS 25 MILLIGRAMS UP TO THIRTEENTH DAY, 50 MILLIGRAMS UP TO TWENTY-SIXTH DAY, AND 75 MILLIGRAMS UP TO THE END OF THE EXPERIMENT. ON JUNE 27 FISH WERE DISTRIBUTED AT A RATE OF 2 KILOGRAMS PER TROUGH. TEMPERATURE OF WATER 13° C.

Items	Terramycin			Average per cent per day	Aureomycin			Average per cent per day	Controls			Average per cent per day
	Replicates				Replicates				Replicates			
	A	B	C		A	B	C		A	B	C	
No. of trout at the start, 6/27/51	210	381	259		223	166	189		217	197	169	
No. of fish inoculated out of total, 6/28	10	10	10		10	10	10		10	10	10	
Mortalities:												
lapsed days 1 to 8 from 6/29	12	22	13	0.7	11	10	10	0.7	11	13	11	4.3
” ” 9 to 13	20	40	21	2.0	25	18	19	2.3	63	43	17	9.6
” ” 14 to 18	41	51	48	4.0	78	54	53	7.6	94	79	32	10.0
” ” 19 to 23	13	26	15	1.8	66	30	31	8.3	30	34	37	6.4
” ” 24 to 28	1	13	4	0.6	24	27	28	9.5	8	7	21	6.8
” ” 29 to 33	1	5	1	0.2	14	7	11	8.2	4	8	14	7.5
” ” 34 to 38		5		0.02	0	3	3	1.5	4	4	9	3.2
Mortalities total, No.	88	162	102		218	149	155		214	188	141	
Mortalities total, per cent	42	43	39		98	90	82		99	95	83	
No. of fish unaccounted for	3	3	11		1	1	13		1	1	1	

on the progress of either disease. Although not indicated in the tables or figures, the mortalities in those fish which were fed pelleted food were about of the same magnitude as in those trout treated with aureomycin and those in the controls.

Although chloramphenicol was not used in this particular experiment, the results previously obtained with adult brook trout (Tables 1 and 2) indicated that the tendency of the infections to reoccur among trout, treated with chloramphenicol, may have been reduced. The number of trout upon which these observations were based were much too small to be of significance. Hence additional tests were made. Those trout which were treated with terramycin and which survived in lots which had been infected with *H. piscium* or *B. salmonicida* were pooled together (into the respective disease groups) and redistributed in equal numbers among four troughs. One-half of these trout were treated with terracon 180 for an additional 9- to 10-day period while the other half was treated for the same length of time with crystalline chloramphenicol. The dosage was 75 milligrams per kilogram of fish per day (Table 5). After completion of this additional treatment the surviving trout were maintained on a normal diet and placed under observation until September 4. There was a significant reduction in the reoccurrence of mortalities due to either *B. salmonicida* or *H. piscium* among the fish which were treated with

TABLE 5. EFFECT OF SUPPLEMENTARY TREATMENT WITH CHLORAMPHENICOL ON THE REOCCURRENCE OF FURUNCULOSIS AND ULCER DISEASE IN FINGERLING BROOK TROUT TREATED WITH TERRAMYCIN. TERRAMYCIN AND CHLORAMPHENICOL WERE ADMINISTERED ORALLY AT A RATE OF 75 MILLIGRAMS PER KILOGRAM OF TROUT PER DAY. NUMBERS INDICATE MORTALITIES AND LETTERS REFLECT THE RESULTS OF BACTERIOLOGICAL EXAMINATION.

Item	Furunculosis[1]			
	Terramycin		Chloramphenicol	
	A	B	A	B
Supplementary treatment period, 8/8 to 8/17/51	1—B.s.	1—B.s.	0	1—B.s.
Post treatment observation period, 8/18 to 9/4/51	4—B.s. 1—n.e.	9—B.s. 3—n.e.	0	
	Ulcer Disease[2]			
	Terramycin		Chloramphenicol	
	A	B	A	B
Supplementary treatment period, 8/13 to 8/22/51	1—n.g.	5—H.p. 1—o. 2—n.g. 3—n.e.	2—H.p.	1—H.p. 1—n.g.
Post treatment observation period, 8/23 to 9/4/51	5—H.p. 1—o. 1—n.e.	8—H.p. 5—n.e.	1—H.p.	1—o.

[1] Each of four replicates contained 125 trout weighing 1.48 kilogram.

[2] Each of four replicates contained 184 trout weighing 2.54 kilogram.

Abbreviations: B.s., *Bacterium salmonicida*; H.p., *Hemophilus piscium*; o., other bacteria, unknown; n.g., no growth on media; n.e., not examined bacteriologically.

chloramphenicol. Table 5 also contains the results of bacteriological examinations of fish which died during the extended period of treatment and observation.

The *in vitro* sensitivity of both *H. piscium* and *B. salmonicida* to several antibiotics was determined in an effort to correlate the possible inhibition of the observed response of fish with the treatment employing some of those antibiotics described.

A modified paper disc method and the Oxford cup method were employed. Several strains of each organism were grown on an enriched solid nutrient medium for 48 hours at 22° C. The resulting growth was suspended in nutrient broth to a suitable density. In order to obtain confluent growth, sterile cotton swabs were used to spread the microorganisms over the surface of either Bacto-heart infusion agar or a solid medium containing fish peptone as described previously (Snieszko, Griffin, and Friddle, 1950).

The modified paper disc method employed Bacto ''sensitivity discs'' as the source of the antibiotic. Each test plate contained discs representing three concentrations of each of the following antibiotics: dihydrostreptomycin, penicillin, terramycin, aureomycin, bacitracin, and chloromycetin. Polymyxin[3] was tested only by the Oxford method. The diameter of the zones of inhibition was measured in millimeters at the end of 24 (*B. salmonicida*), or 48 hours (*H. piscium*) of incubation at 22° C. The results of these tests are recorded in Table 6.

An attempt was made to demonstrate possible bacteriostatic activity present in the blood of groups of fish which had been receiving terramycin and aureomycin at dosage levels of 24-30 milligrams per kilogram of fish per day and aureomycin at 75 milligrams per kilogram of fish per day. The blood taken from two groups of fish each maintained at these levels of treatment was tested. One group had been treated over a period of 3 days and the other for a period of 8 days.

The blood was obtained from the fish by cutting off the tail and allowing two drops to fall on a sterile disc made from Whatman No. 40 filter paper by using a #4 cork borer.

The discs, prepared in this manner, were placed on solid media which had been seeded as previously described. Observations were made at the end of 48 hours of incubation at 22° C. It was found that inhibiting zones were absent regardless of the treated group tested.

DISCUSSION AND RECOMMENDATION FOR TREATMENT

The *in vitro* growth inhibitions of *B. salmonicida* and *H. piscium* by terramycin and chloramphenicol correlated rather well with the

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[3] Kindly furnished free of charge by Burroughs Wellcome and Co., Tuckahoe, N. Y.

TABLE 6. SENSITIVITY OF *H. PISCIUM* AND *B. SALMONICIDA* TO ANTIBIOTICS *IN VITRO* AS TESTED BY THE BACTO SENSITIVITY DISCS.[1] FIGURES REPRESENT DIAMETERS IN MILLIMETERS OF ZONES OF GROWTH INHIBITION.

	Bacitracin Units			Chloro-mycetin mcg			Dihydro-streptomycin mcg			Aureomycin mcg			Terramycin mcg			Penicillin Units			Polymyxin mcg		
	2	10	20	10	30	60	0.5	1.0	10	10	30	60	10	30	60	0.5	1.0	10	10	30	500
Hemophilus piscium[2]	0	8	10	38	42	52	0	10	30	11	22	22	15	36	38	0	0	0	3	5	10
Bacterium salmonicida[2]	0	0	8	29	33	38	0	0	12	17	23	24	28	31	34	0	0	12	1	4	7

[1] With the exception of Polymyxin B (Sulfate), "Aerosporin" brand, kindly supplied by Burroughs, Wellcome & Co., Tuckahoe, N. Y., this substance was tested by means of a modified Oxford cup method.

[2] The figures represent the average obtained from tests employing four strains of each organism.

results obtained *in vivo* in fish treated by the oral administration of these antibiotics. However, this did not appear to hold true in the case of aureomycin. Feeding this antibiotic, either in the crude or pure form, to fish exposed to infection did not result in any significant reduction in mortalities as one might have expected on the basis of the *in vitro* demonstration of fairly good zones of inhibition. It is possible that this antibiotic was inadequately absorbed from the intestinal tract of fishes. Since only preliminary tests were made on the presence of antibiotics in fish blood. it would be too early to speculate further as to the reason aureomycin had no therapeutic value. Chloramphenicol was apparently more effective in the elimination of pathogens from fish with latent infections. This was evident from the greatly reduced mortalities during the post-treatment observation period.

The data obtained from the method which utilized commercially available paper discs, treated with various antibiotics, are suggestive of a practical and easy method of determining the treatment of fish infections of bacterial origin even before a complete identification of the etiological agent has been made.

On the basis of the findings reported by Smith (1950), as well as in our preliminary work, and the data presented in this paper, the authors feel justified to recommend the use of certain antibiotics in cases of bacterial infections of lower vertebrates. With fishes, the minimum effective oral dosage is 50 milligrams per kilogram of body weight per day. To be certain that the dosage is adequate and to provide a wide margin of safety, it may be even better to increase the dosage up to the maximum of 75 milligrams per kilogram of body weight per day at least during the first several days of treatment. The treatment should be started as soon as possible after the outbreak of the disease, since those individual fish with advanced stages of infection may not be able to take the medicated food. All visibly sick fish should be removed and destroyed because they may not be saved and very probably will serve as a reservoir of the pathogen.

The treatment should be continued until the epizootic is brought completely under control. This may be achieved after 10 to 15 days provided treatments are started soon enough. In cases of more advanced infection, the treatment should be continued until the mortalities due to the disease are reduced to zero. It must be kept in mind that in a population of apparently healthy fish there are continuous small losses due to various and usually undetermined causes.

Every effort should be made to diagnose the disease correctly. In those cases in which one suspects furunculosis, ulcer disease, or a mixed infection, a bacteriological examination should be made. Furunculosis can be treated with sulfonamides effectively and less expensively than any other known method. In instances of ulcer disease or a frequently occurring mixed infection with *H. piscium* and *B. salmonicida,* antibiotics should be used.

When terramycin is used for treatment, a more permanent control of the infection may be achieved by replacing terramycin with chloramphenicol during the last 4 to 6 days of therapy. Should drug-fast mutants of the pathogen appear during the treatment with terramycin, the use of another equally effective antibiotic like chloramphenicol may be greatly beneficial. It is believed that in the event of a mixed infection caused by *H. piscium* and *B. salmonicida,* sulfamerazine and terramycin or chloramphenicol can be given at the same time Both should be given at the full dosage rate assumed on the basis of the information available on the sulfonamide therapy of furunculosis (Snieszko and Friddle, 1951; Flakas, 1950).

As in the treatment of furunculosis with sulfonamides, it is equally important, when employing antibiotics, to give all fish an opportunity to obtain an adequate amount of the drug. Therefore, the distribution of antibiotics in food should be very uniform. For best results and in terms of economy, the fish should be fed the drugs judiciously, using no more or less food than will be taken readily by the fish. The fish should be well graded and the runts should be removed to insure a more equal consumption of medicated food. Since most of the fish diets contain meat or other components which may spoil rapidly, the feed containing the drug should be prepared no more than 2 days in advance and stored under refrigeration.

Every possible sanitary measure should be taken to prevent the spread of disease to other parts of the hatchery. It is fortunate that both furunculosis and ulcer disease can be cured but this fact in no way should lead to the relaxation of measures which may prevent the outbreak or spread of these diseases altogether. No drug can eliminate a disease completely from an entire population. It can only reduce losses when the disease strikes and the cost of treatment in money and labor is usually considerable. The only effective measures against reoccurrence of infectious fish diseases is to eliminate all possible sources of infection. Adult fish, even though not showing symptoms of a disease, may frequently act as carriers of microorganisms which cause destructive epizootics among younger fish.

SUMMARY

Data are presented which indicate that either terramycin or chlo-

ramphenicol, administered orally at a rate of 50 milligrams per kilogram of body weight of fish per day, is highly effective in the treatment of infections in brook trout caused by either *Hemophilus piscium* or *Bacterium salmonicida.* To provide a broad margin of safety, a dosage level of 75 milligrams of antibiotic is recommended especially during the first several days of treatment.

Aureomycin and a commercial brand of fish pellets (reported to contain a certain antibiotic) were ineffectual in the treatment of ulcer disease or furunculosis in brook trout. It is interesting to note that, *in vitro,* aureomycin did inhibit the growth of both *B. salmonicida* and *H. piscium.* However, the effect was not as pronounced as that of chloramphenicol or terramycin.

Since the data presented in these experiments indicate that chloramphenicol is very effective in reducing the reoccurrence of mortalities caused by infection with either *H. piscium* or *B. salmonicida* in trout which had previously been treated with terramycin, it is suggested that during the last 4 to 6 days of treatment terramycin should be replaced by chloramphenicol.

The indiscriminate use of antibiotics is discussed. Antibiotics should not be considered as panacea and cannot be relied upon to keep infectious fish diseases away from the hatchery. Without elimination of all possible vectors and reservoirs of infections, even the so-called "miracle drugs" cannot produce lasting results.

LITERATURE CITED

Baron, A. L.
1950. Handbook of antibiotics. Reinhold Publishing Corporation, New York City, 303 pp.

Calkins, G. N.
1899. Report upon the recent epidemic among brook trout (*Salvelinus fontinalis*) on Long Island. Fourth Ann. Rpt., N. Y. Comm. Fish, Game and Forests, 175-189.

Duel, C. R., D. C. Haskell, and A. V. Tunison
1942. The New York State fish hatchery feeding chart. Fisheries Res. Bull. No. 3. Revised edition, 38 pp.

Emmerich, R., und E. Weibel
1894. Uber eine durch Bakterien erzeugte Seuche den Forellen. Arch. f. Hygiene, 21:1-24.

Fish, F. F.
1934. Ulcer disease of trout. Trans. Am. Fish. Soc. 64:252-258.

Flakas, K. G.
1950. Sulfonamide therapy for furunculosis in brown trout. Trans. Am. Fish. Soc. 78: 117-127.
1950. Bacteriological findings in the study of an outbreak of ulcer disease among brook trout yearlings of the Westfield, Wisconsin, Hatchery. The Prog. Fish Culturist 12(2):63-66.

Gutsell, J. S.
1948. The value of certain drugs, especially sulfa drugs, in the treatment of furunculosis in brook trout, *Salvelinus fontinalis.* Trans. Am. Fish. Soc. 75:186-199.

Hofer, B.
1904. Handbuch der Fischkrankheiten. Muenchen.

Marsh, M. C.
1905. The Cold Spring Harbor epidemic among trout. Ann. Rept. Forest, Fish and Game Comm., State of New York 10:125-139.

Reed, G. B., and G. C. Toner
1942. *Proteus hydrophilus* infection of pike, trout and frogs. Can. J. Research 20: 161-166.
Smith, S. W.
1950. Chloromycetin in the treatment of "red leg." Science 112(2906):274-275.
Snieszko, S. F., and S. B. Friddle
1950. A contribution to the etiology of ulcer disease of trout. Trans. Am. Fish. Soc. 78:56-63.
1951. Tissue levels of various sulfonamides in trout. Trans. Am. Fish. Soc. 80:240-250.
Snieszko, S. F., S. B. Friddle, and P. J. Griffin
1951. Successful treatment of ulcer disease in brook trout (*Salvelinus fontinalis*) with terramycin. Science 113(2947):717-718.
Snieszko, S. F., P. J. Griffin, and S. B. Friddle
1950. A new bacterium (*Hemophilus piscium*, n. sp.) from ulcer disease of trout. Jour. Bacteriology 59(6):699-710.
Tunison, A. V., and C. M. McCay
1937. The nutrition of trout. Cortland hatchery report No. 6. New York State Cons. Dept., Albany, N. Y., 24 pp.
Wolf, L. E.
1939. Observations on the ulcer disease of trout. Trans. Am. Fish. Soc. 68:136-151.
1941. Further observations on ulcer disease of trout. Trans. Am. Fish. Soc. 70:369-381.
1947. Sulfamerazine in the treatment of trout for furunculosis and ulcer disease. Prog. Fish Culturist 9(3):115-124.

DISCUSSION

DISCUSSION LEADER HERMAN: Dr. Snieszko, I would like to ask what the incidence is of this disease in your captive animals, and whether you have any information on what the incidence is in the native trout in the streams.

DR. SNIESZKO: These diseases are the most dreaded diseases of trout, particularly brook trout. In New England, now, these diseases in brook trout are such that many hatcheries are forced to close.

Of course, treatment of fish with antibiotics is quite expensive, and therefore we do not recommend continuous treatment.

Treatment should only be given if the disease breaks out and there is no other means of control. The only alternative would be to kill the remaining fish. I would never recommend continuous treatment with antibiotics since this would not be economically feasible.

Of course, since treatment is only possible by feeding medicated food, it would not be possible to treat the fish which are in the natural waters. The treatment of fish is only possible in hatcheries.

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CERCARIA MILFORDENSIS NOV. SP., A MICROCERCOUS TREMATODE LARVA FROM THE MARINE BIVALVE, *MYTILUS EDULIS* L. WITH SPECIAL REFERENCE TO ITS EFFECT ON THE HOST

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Cercaria milfordensis was found by the writer in April, 1951 in 4 of 93 (4.3%) intertidal specimens of the common mussel, *Mytilus edulis,* from Mill Neck, Long Island, New York. Subsequently, this larva was found in *Mytilus* from Milford and Bridgeport, Connecticut, in both intertidal and subtidal areas where 30 of 454 (6.6%) mussels collected in 1951 and 44 of 567 (7.7%) in 1952 were found to be infected. Consultation with Dr. V. L. Loosanoff, Director of the U. S. Shellfish Laboratory at Milford, revealed that in 1936, he also had observed the parasite in *M. edulis* from Milford Harbor. Dr. Loosanoff kindly made available a collection of slides of adult *Mytilus* gonad tissue collected at biweekly intervals during the period June 1936–June 1937. Examination of this material showed that 12 of 174 (6.9%) specimens of *Mytilus* were infected with the microcercous larvae.

Previous records of cercariasis in *Mytilus* spp. are European in origin and pertain to the larvae of three trematode species. Dubois (1901, 1903, 1907, 1909) described larval stages of *Gymnophallus margaritarum* [= *Distomum margaritarum* Dubois, 1901] from *M. edulis* and *M. gallo-provincialis.* The metacercaria of this species has held particular interest as a cause of pearl formation in *Mytilus* and other bivalve species, and many conflicting accounts were rendered concerning its biology and identity. Palombi (1924) re-studied the species in *M. gallo-provincialis* in an attempt to clarify the conflicting opinions of the time and concluded that the "pearl trematodes" of Jameson (1902) and later authors were identical with the species of Dubois. Cole (1935) described two cercarial forms, *Cercaria tenuans* and *Bucephalus mytili,* from *M. edulis* in British waters; infection with the former species was termed "orange-sickness" from the orange color imparted to the mantle lobes of infected mussels by masses of orange-pigmented sporocysts. A similar gross appearance is characteristic of mussels heavily infected with the trematode larvae discussed here.

The specific name *milfordensis* is proposed for this larval distome in consideration of the evidence of consistent and long-standing endemic frequency in this locality. It is noteworthy, perhaps, that this parasite has not been reported before from higher latitudes where *M. edulis* has been studied for many years. The writer had previously examined over two thousand specimens of *M. edulis* from Newburyport and Gloucester, Massachusetts, without finding this trematode parasite. It should be noted that the endemic areas cited are quite localized with respect to each other. The Connecticut localities are in close proximity and separated from the New York area only by the north-south reaches of Long Island Sound. Ecologically, the intertidal collecting areas are practically identical, the Sound between them notwithstanding.

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The following description is based on a study of naturally emerged cercariae, both living and preserved, and on cercariae within the sporocysts. Permanent preparations of sporocysts and cercariae killed in hot formalin, secondarily fixed in Dubosc-Brasil fluid, and stained with borax-carmine were especially useful for morphological details and measurements which, except where noted, are from permanent preparations of cercariae within sporocysts. Such measurements are considered more accurate than those obtained by other methods. The opacity of living, or unstained, uncleared larvae prevents satisfactory measurement of organs without excessive coverslip pressure and resultant exaggeration of size. Standard histological procedures were followed for a detailed study of the host-parasite relationships. Several combinations of fixatives and stains were employed, the most satisfactory being a Zenker acetic—Iron hematoxylin schedule.

Cercaria milfordensis n. sp.
(Figs. 1–2. All measurements in millimeters)

The cercariae are small, stout-bodied, microcercous distomes produced in simple, saccate, motile, orange-pigmented sporocysts in the gonad and digestive gland of *M. edulis*. One hundred ripe sporocysts measured from 0.857 to 1.652 in length with a mean value of 1.246. The sporocysts occur primarily in the blood sinuses and interfollicular lymph spaces of the mantle gonad where infection leads to suppression of gametogenesis or complete atrophy of the reproductive organs. The cercarial bearing sporocyst generations are preceded by, and also accompanied by, smaller, non-pigmented sporocysts which have not been observed to contain other than undifferentiated germ balls. Whether this is a distinct sporocyst generation, or a younger stage of the cercarial generation, remains to be determined. In any event, these antecedent stages are dominant from July to October after which they rapidly give way to cercarial generations which persist and dominate in numbers to a period of maximum development in April, May, and June. In subtidal infections, maturation of cercariae may be attained even later, presumably as a direct result of the lower prevailing temperature. Mature infections with sporocysts containing more than one hundred cercariae were found in several specimens of *Mytilus* collected July 3, 1952 at Bridgeport, Conn. in 10 feet mean low water.

Fully developed, spontaneously emerging cercariae are pyriform, oval or elongate in outline depending upon the degree of contraction. The observed size range of a series of such living larvae was from 0.147 to 0.525. The dimensions of a series of fixed, stained, and mounted larvae were 0.221 to 0.284 in length, by 0.072 to 0.084 in width, with mean values of 0.254 by 0.075.

The oral sucker is relatively large, oval to spherical, usually longer than broad, with the oral opening subterminal in position; it varies from 0.040 by 0.038 to 0.045 by 0.041 with mean values of 0.043 by 0.038. The short prepharynx is 0.002 to 0.004 in length. A subspherical pharynx averaging 0.020 by 0.024 is followed by a short, hyaline esophagus joined by broad digestive ceca that extend to a level slightly posterior to the bifurcation of the excretory vesicle. The walls of the ceca are composed of large polygonal cells which are readily demonstrated with neutral red.

The acetabulum is spherical, slightly larger than the oral sucker, and from 0.045 to 0.051 in diameter with a mean value of 0.048. The approximate sucker-pharynx-acetabulum ratio is 2 : 1 : 2.

A small spherical tail measuring only 0.010 to 0.013 in diameter is characteristic of this larva. It is weakly attached to a slight posterior invagination of the body and apparently is without useful function; it may be either lost while the cercariae are still confined to the sporocyst, or retained for several days after emergence.

The excretory vesicle is Y-shaped with the stem shorter than the arms which extend anteriorly and terminate at the esophageal level where they receive the primary tubules. Details of the excretory system were obscured by abundant unicellular glands. Some of the larger of these are figured to show their irregular distribution. Three pairs of cephalic gland ducts emanate from the post-pharyngeal region and terminate in six separate pores on the dorsal lip of the oral sucker. The cephalic gland cells could not be located with any certainty in either living specimens or in permanent preparations. Some of the gland cells figured probably are cephalic glands, while the others are cystogenous in function.

Survival experiments were conducted with emerged cercariae in filtered sea water at 21.0°, 14.0°, and 7.0° C. ± 1.0° C. At 21°, the larvae survived only 24 to 48 hours, whereas at 14°, little or no mortality occurred in replicates until the fourth day and all larvae were dead or moribund by the seventh day. At 7°, five groups of fifteen larvae each were maintained without mortality for seven days while after twelve days, twenty-nine of the original seventy-five larvae were still active. While it has not been established that spontaneous emergence of cercariae occurs more frequently at any particular temperature, it is important to note that maturation of cercarial generations occurs during late winter and spring when the annual temperature cycle is at its lowest (2°–8° C.).

The behavior of *C. milfordensis* offers little direct information bearing on the life cycle. The larvae do not manifest any pronounced taxes, and their role in completing the life cycle appears to be decidedly passive in contrast to the host seeking efforts of many other cercariae. The only activity after emergence consists of periodic contraction and elongation which effects a serpentine but random progress upon the substratum. The suckers, though powerful and well developed, are seldom used in this progress. The survival experiments suggest that increased longevity outside the molluscan host may compensate for the lack of natatory ability.

HOST-PARASITE RELATIONSHIPS

C. milfordensis is primarily a parasite of the blood vascular system of its host, *M. edulis.* Sporocyst development and asexual multiplication are particularly confined to three mutually related elements of the venous system serving the mantle region. In ascending order of importance, these main groups are: (1) the paired *longitudinal veins* which are central collecting sinuses for blood from all parts of the body; (2) the *external plicate canals,* accessory respiratory lymph channels which transfer venous blood from the greater part of the mantle to the longitudinal veins; (3) the paired *horizontal veins* of the mantle which receive blood from the many ascending pallial veins of that organ and deliver it through the external plicate canals to the longitudinal veins. Among these elements of the vascular system, the horizontal veins are primary foci of infection.

Beginning with the early development of definitive sporocyst generations in late fall, there is a pronounced accumulation of immature and rapidly developing sporocysts within the horizontal veins which course along the entire length of the dorsal level of the mantle slightly below the angle formed by the junction of the mantle and the gill filaments. Eventually the veins become dilated and tightly packed with sporocysts (Fig. 5) which continue to mutiply and grow, forcing their way downward and into the mantle through the ascending pallial veins. The vascular system of the mantle eventually loses its organized continuity through rupture of the lymph bearing vessels and appears finally as a more or less continuous hemocoel with sporocysts pervading throughout.

The pathological consequences following this infection are both mechanical and physiological. The "blocking layer"[1] of sporocysts developing in the horizontal veins of the mantle causes a serious reduction in the efficiency of the entire circulatory system. The more important effect, however, is the impingement upon the circulation of the mantle itself, which is destined, seasonally, to become the major seat of gametogenesis. Unfortunately for the host, sporocyst development coincides with the period of annual gonadal development. In addition to these more obvious considerations, the potentially toxic effects of the larval metabolites must be suffered by the host.

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[1] The "blocking layer" of Rees (1936), as originally described, referred to inactive, nonmigratory sporocysts which multiplied and remained in a tightly compacted, circumscribed location. The expression is fitting, nevertheless, for the sporocysts of *C. milfordensis*.

The reproductive system of *M. edulis* consists of a racemose complex of genital ducts and follicles which ramify throughout the visceral mass and the mantle lobes. The greater part of the system, however, occupies the mantle lobes which in normal individuals are distended with reproductive tissue prior to spawning (Figs. 3, 4). Although *M. edulis* is normally dioecious, hermaphroditism may occur rarely. During the course of this study, one instance of bisexuality was observed. At the time of sexual ripeness (April, May, and June in these waters) the sexes may be distinguished by the color of the gonadal mass in the mantle; the ripe male gonad appears whitish, while the female follicles with included ova impart a coral to orange color to the mantle. Mussels are sexually spent by late July or early August and the follicles and residual sex products undergo the process of resorption. During this resting phase the mussels accumulate reserve nutritive materials preparatory to a new annual sexual cycle commencing in the late fall. Concurrent with the onset of renewed gametogenic activity, the sporocysts of *C. milfordensis* invade and mass in the dorsal region of the mantle gonad. The blocking layer is most characteristic at this time of the year as asexual multiplication of sporocysts leads to early cercarial development. Sporocyst development precludes normal gametogenesis; follicular development, if it has proceeded at all, is seriously impaired. Larval development in infected mussels keeps pace with the gametogenic processes of normal individuals and it appears that the parasite has advantageously chosen its host's most active period of reproductive activity to serve its own needs. Maximum development and maturation of cercarial generations occurs during the spring. Figure 6 shows the appearance of a portion of the mantle gonad of a male mussel with mature sporocysts dominating the organ. Although the specimen represented was collected in early July in subtidal waters, it is typical of the condition prevailing in the spring in mussels from intertidal areas.

The ability of the host to survive infection has not been determined. During the spring of 1952, however, 30 specimens of infected *Mytilus* were isolated and maintained in trays of running sea water in the laboratory and all but two of these died during the summer. While controls were not kept, it is assumed that the mortality was abnormally high since prior observation of healthy mussels held under similar conditions showed them to be very hardy. The two survivors were dissected in late November and gave proof that infection persists beyond one cycle at least. One specimen contained only sporocysts with undifferentiated germ balls, presumably daughter generations, while the other contained these and cercarial generations as well. The severe intensity of the parasitism suggests that *C. milfordensis* infections are probably lethal under temporary or sustained periods of ecological conditions unfavorable to the host.

C. milfordensis is tentatively referred to the FELLODISTOMATIDAE, the members of which mature in marine fishes. The proposal is based upon the discovery of several specimens of unencysted progenetic larvae referable to the genus *Proctoeces* in the visceral mass of three mussels bearing *C. milfordensis* infections. Morphological comparison of the two forms is favorable, and if the apparent relationship truly exists, an abbreviated life cycle may be possible since the larval *Proctoeces* contain many eggs with well developed, motile miracidia. Experimental studies are projected and it is hoped that decisive information can be presented at a later date.

Buttner (1950) presented a comprehensive review of progenesis in the DIGENEA and listed 34 progenetic species representing 12 families. The present study adds a new family and genus to those compiled by Buttner and provides further evidence that progenesis may be more common than has been suspected.

I wish to express my sincere appreciation to Dr. Horace W. Stunkard, of New York University, for generous counsel. Acknowledgment is due to J. W. Lownsbery for technical assistance and to C. A. Nomejko for preparation of the photomicrographic figures.

REFERENCES

BUTTNER, A. 1950 La progénèse chez les trématodes digénétiques, sa signification, ses manifestations. Contributions à l'étude de son déterminisme. Ann. Parasitol. **25**: 376–434.

———1951 La progénèse chez les trématodes digénétiques (fin). Etudes de quelques métacercaires à évolution inconnue et de certaines formes de développement voisines de la progénèse. Conclusiones generales. Ann. Parasitol. **26**: 279–322.

COLE, H. A. 1935 On some larval trematode parasites of the mussel (*Mytilus edulis*) and the cockle (*Cardium edule*). Parasitology **27**: 276–280.

DAWES, B. 1946 The Trematoda. 644 pp. Cambridge.

DUBOIS, R. 1901 Sur le mode de formation des perles dans *Mytilus edulis* L. C. R. Assoc. Franc. Avanc. Sc. Part I: 149–150.

———1903 L'origine des perles chez le *Mytilus gallo-provincialis*. C. R. Acad. Sc. Paris. **136**: 178.

———1907 Sur les métamorphoses du distome parasite des *Mytilus* perliers. C. R. Soc. Biol. Paris **63**: 334–336.

———1909 Contribution à l'étude des perles fines, de la nacre, et des animaux qui les produisent. Ann. Univ. Lyon (N.S.) Fasc. **29**: 1–126.

FIELD, I. A. 1922 Biology and economic value of the sea mussel, *Mytilus edulis*. Bull. U. S. Bur. Fisheries **38**: 127–259.

JAMESON, L. H. 1902 On the origin of pearls. Proc. Zool. Soc. London **1**: 140–165.

LEBOUR, M. V. 1911 A review of the British marine cercariae. Parasitology **4**: 416–456.

MANTER, H. W. 1940 Digenetic trematodes of fishes of the Galapagos Islands and the neighboring Pacific. Rep. Coll. A. Hancock Pacific Exp. 1932–38, **2**: 329–497.

NEWCOMB, C. L. 1935 A study of the community relationships of the sea mussel, *Mytilus edulis* L. Ecology **16**: 234–243.

PALOMBI, A. 1924 Le cercarie del genere *Gymnophallus* Odhner dei mitili. Pubbl. Staz. Zool. Napoli **5**: 137–152.

REES, W. J. 1936 The effect of parasitism by larval trematodes on the tissues of *Littorina littorea* (Linné). Proc. Zool. Soc. Lond.: 357–368.

STAFFORD, V. 1912 On the fauna of the Atlantic Coast of Canada. Third report—Gaspe, 1905–1906. Contrib. Canad. Biol. 1906–1912: 45–67.

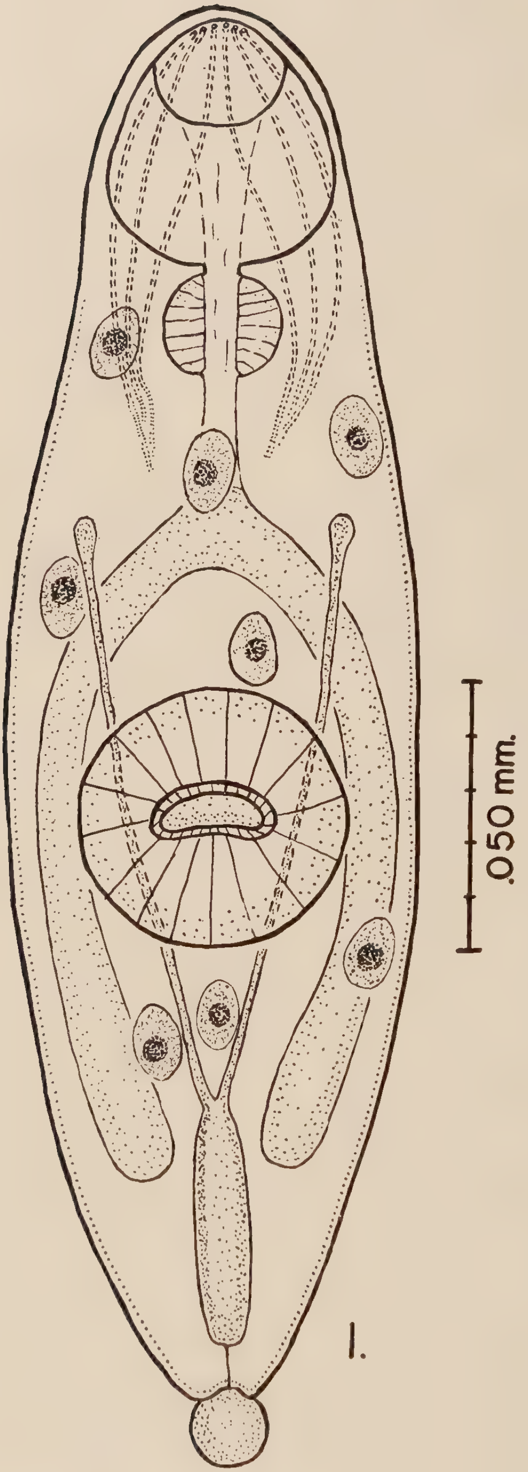
EXPLANATION OF FIGURES

PLATE I

FIG. 1. *Cercaria milfordensis,* ventral view. Camera lucida outline drawing with freehand detail.

FIG. 2. *C. milfordensis,* lateral view. Camera lucida outline drawing.

PLATE I



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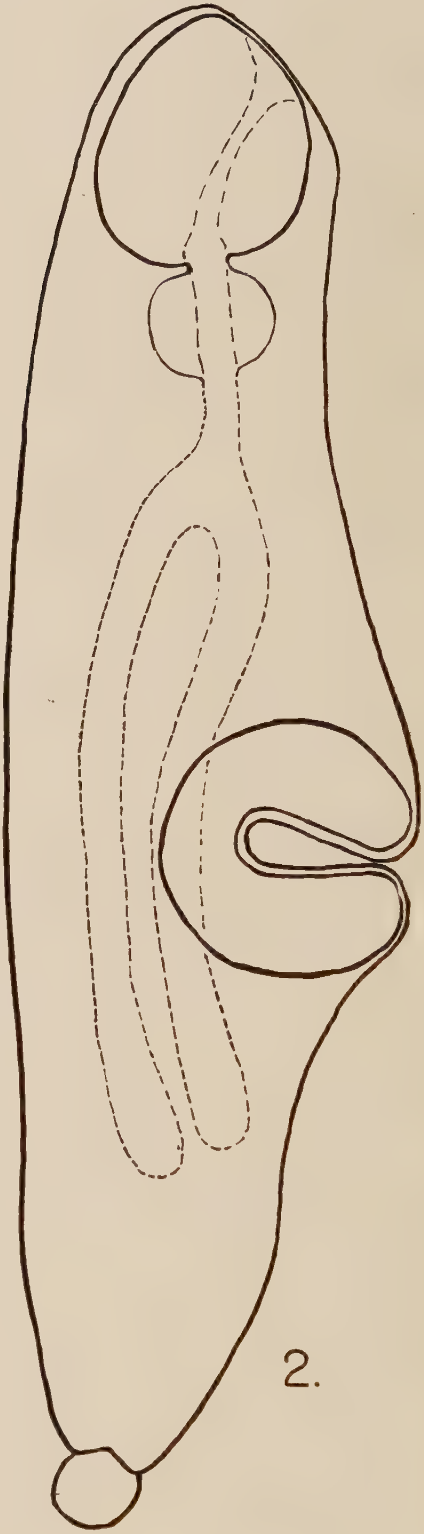

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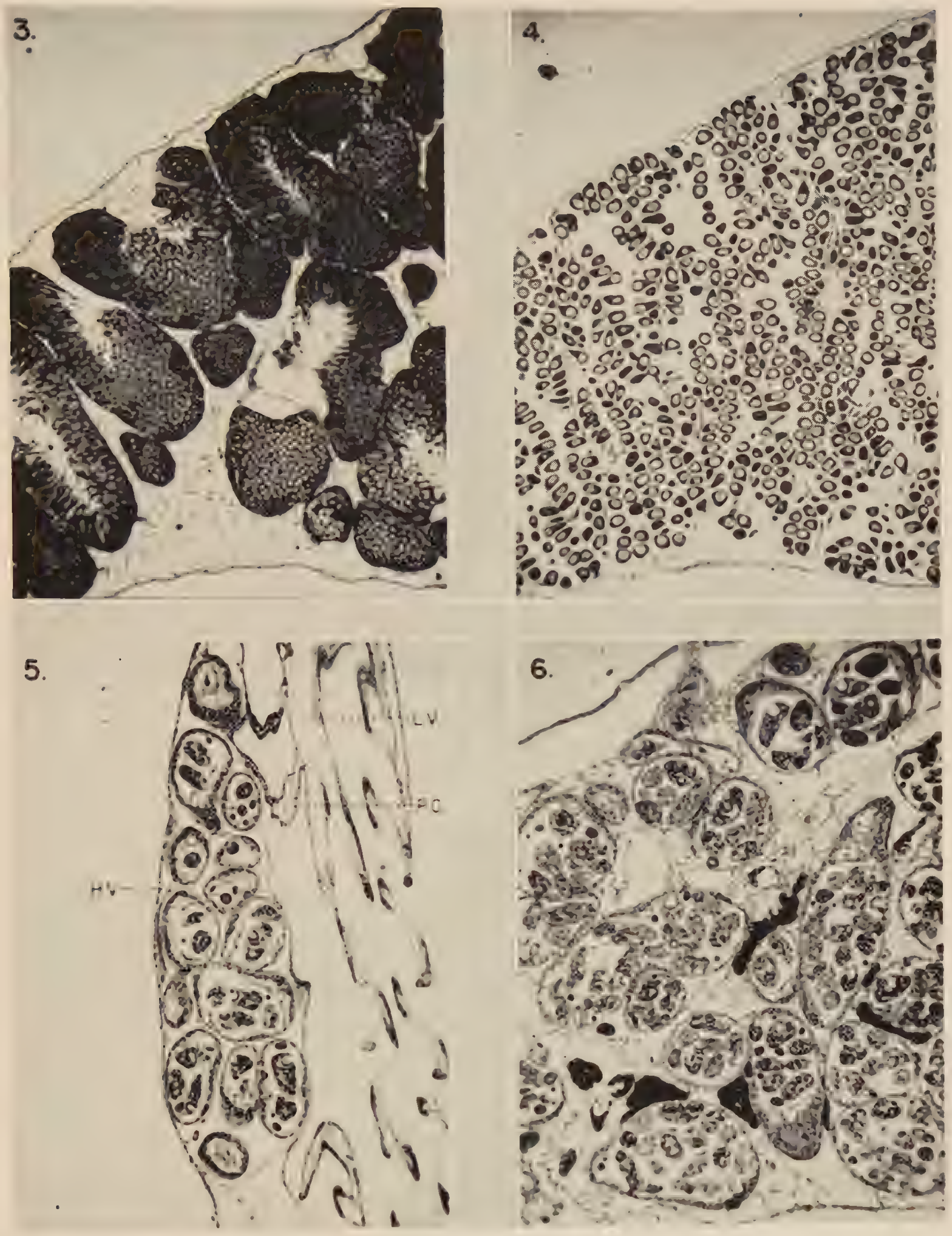

PLATE II

FIG. 3. *Mytilus edulis,* male gonad. Photomicrograph of transverse section through dorsal portion of mantle gonad at mid-body level. Typical appearance of mature follicular complex. Note cords of spermatozoa extending into lumina of follicles. Preserved in April.

FIG. 4. *M. edulis,* female gonad. Plane of section same as Fig. 3. Typical ripe female preserved in April showing follicular arrangement and undischarged ova.

FIG. 5. Parasitized *M. edulis,* sex indeterminate. Section through dorsal level of mantle and gills near point of junction showing early formation of blocking layer of *C. milfordensis* sporocysts within horizontal vein (HV). LV, longitudinal vein; PC, external plicate canal. Preserved in November.

FIG. 6. Parasitized *M. edulis,* male. Plane of section same as Figs. 3 and 4. Typical appearance of heavily parasitized gonad with mature sporocysts dominating entire organ. Deeply stained areas are persisting remnants of atrophied male follicles. Compare with Fig. 3. Preserved in early July.

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TUNA FISHING AT TAHITI

By **Wilvan G. Van Campen***

In February of this year the U. S. Fish and Wildlife Service's vessel John R. Manning, operating from Pacific Oceanic Fishery Investigations' Honolulu base and fishing a series of tuna long-lining stations across the equatorial current system on 140° and 150° west longitude, put in at Papeete, Tahiti, for refueling. Some observations of the Tahitian tuna fishery were made with the primary objective of picking up any information on fishing methods which might be applicable elsewhere in the Pacific, particularly in those United States island possessions which need an augmented protein food supply or which are considered potential locations for tuna-cannery development. In this latter connection, interest in the Tahitian situation was heightened by the fact that on another recent POFI cruise some samples of tuna canned in Tahiti were obtained in the Marquesas, and it was anticipated that Tahiti might prove to be a model of an isolated tropical island with a small population and limited technical resources (i.e. like America Samoa) which was nevertheless able to keep a tuna cannery in operation (as Samoa has so notably not been able to do).

It was found, in fact, that the Tahitian tuna fishery is quite primitive in nature, and that it has not proven capable of supporting even a modest canning industry in normal times, although it does supply abundant and fairly cheap fresh fish to the Island's people. The information obtained in the course of a brief stay at Papeete is necessarily incomplete, and is derived more from interviews with local people than from first-hand observation; however, it may be of some general interest in the absence of any more complete accounts.

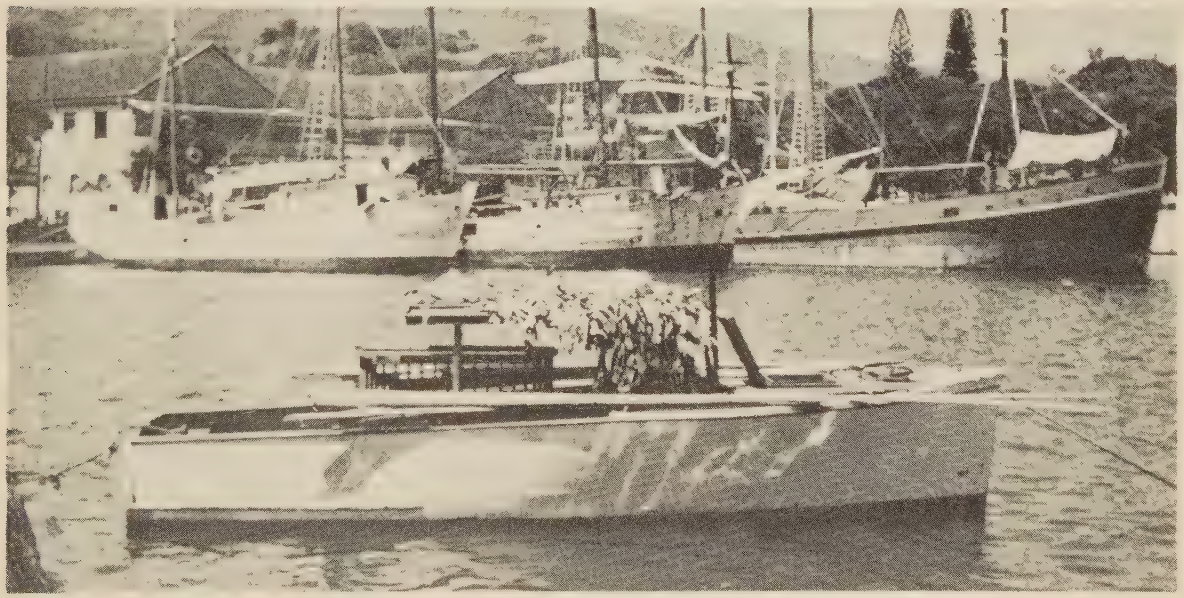

FIG. 1 - A TYPICAL TAHITIAN TUNA BOAT IN PAPEETE HARBOR. NOTE THE FISHING POLES ALONG THE SIDES AND THE BUNDLE OF DRY LEAVES FOR SHADE ON THE COCKPIT CANOPY.

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The tunas commonly taken at Tahiti are the yellowfin (*Neothunnus macropterus*), called "thon" in French and "a'ahi" in Tahitian, and the skipjack (*Katsuwonus pelamis*), called bonite in French and auhopu in Tahitian. No big-eyed tuna, albacore, or little tuna were seen in the market, nor did the persons interviewed appear to recognize descriptions of these species. Some informants spoke of another kind of tuna called *va'o*, apparently the dog-toothed tuna, which was said to be abundant around the reefs and passes of the Tuamotus, though less common around the high islands. The yellowfin and skipjack seen in the market and being unloaded from the fishing boats were of very mixed sizes, ranging from an estimated 5 pounds to about 50 or 60 pounds each in the case of yellowfin and to perhaps 40 pounds each for the skipjack. When the observer remarked on the unusually large size (by Hawaiian standards of comparison) of some of the skipjack, he was told that even larger ones--up to 70 pounds--were sometimes brought in. Although this might be an exaggeration, it is interesting to note that a news story in the *Pacific Fisherman* of March 1950 contains a report of three-pole skipjack tuna (75 pounds) taken by a Hawaii-based vessel which fished in the Tahiti area.

The Tahitian tuna boats are of uniform design, about 18 to 25 feet in length, and very much like small sport-fishing cruisers in general appearance. They are powered with 9 to 18 hp. Diesel engines of French manufacture. They carry no ice. The catch is kept on the floor of the small cockpit. Their only water supply is a bottle filled on the quay, and the only visible concession to comfort is a heap of dried leaves on the roof which is supposed to keep the cockpit cool. Each boat carries three fishermen, and there are said to be about 20 such boats at Tahiti, most of them based at Papeete. The boats are almost all owned by people ashore, and the proceeds are split 50-50 between the owner and the fishermen. The operating radius of the fleet is about 30 miles from Tahiti. The normal schedule is to put out to sea at around 8:00 a.m. and return at anywhere from 5:00 p.m. to midnight. The boats fish all around the island of Tahiti, often cross the 8-mile channel to Moorea, and sometimes go as far as the atoll of Tetiaroa, 25 miles north of Tahiti, where the fishermen sleep on the beach all night.

The tuna schools are located by sighting the flocks of birds which accompany them, and the fishing is done with pole and line, using pearl-shell jigs of the traditional Polynesian type. The poles, of which four or five are carried lashed along the gunwales on each side of the boat, are about 12 to 16 feet long, of a light, thin-walled local bamboo. They are perfectly plain, with no serving or wrapping on the grip. The line is slightly shorter than the pole. While fishing, the boat is kept under way and moving with the school at all times, and the pearl-shell jig is slapped and played on the surface in such a way as to attract the tuna. Live bait is never used, nor is there any spray or splashing of water over the lure. As in all islands where the Polynesian method of tuna fishing is used, it is believed that fine nuances of color in different shell hooks in relation to light conditions and to the color of the natural feed which the tuna are taking have an important effect on the success of the fishing. While on a school, the fishermen change lures frequently in order to find the one which will be most attractive to the fish. Differences in color and sheen imperceptible to the unpracticed eye may give one hook a very high value while another apparently identical one will be considered almost worthless. Pearl shells from certain islands, or from certain spots on the reefs of certain islands, are reputed to make especially effective hooks.

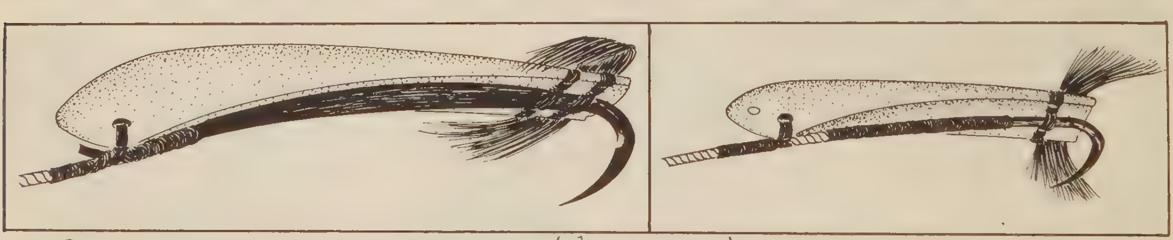

FIG. 2 - TAHITIAN TUNA LURES. THE SMALLER HOOK ($3\frac{1}{2}$ INCHES LONG) IS OF THE TYPE USED FOR SKIPJACK, THE LARGER ($5\frac{1}{2}$ INCHES LONG) IS FOR LARGE YELLOWFIN. THE BODY OF THE LURE IS MADE FROM THE THICKEST PART OF A PEARL OYSTER SHELL, THE HOOK IS OF BEATEN COPPER, AND THE TUFT OF PIG BRISTLES AT EACH SIDE OF THE AFTER END IS SUPPOSED TO KEEP THE JIG IN THE PROPER POSITION AS IT IS TRAILED ON THE SURFACE.

In addition to the jigging of fish from surface schools, large tuna and marlin are sometimes hand-lined from canoes at well-known "tuna holes" ('apo'o a'ahi), some of which are quite close to the reef. Trolling appears to be completely unknown as a commercial fishing method, but occasionally when a boat is fishing a school and large yellowfin tuna show up mixed with the smaller fish they are taken on hand lines with cut bait.

The seasons for tuna fishing at Tahiti are said to be January-March and July-August, but some fish are taken throughout the year. It was reported that the same sizes of fish are present in Tahitian waters at all times of the year. Unfortunately, the seasons of abundance of the tunas coincide with the peak seasons for the atule (big-eyed scad, Selar crumenophthalmus), which is generally preferred by the Tahitians. Thus, when big catches of atule and tuna come into the market at the same time, the tuna may be sold at give-away prices, or they may even have to be thrown away. No use is made of refrigeration, nor of salting or sun-drying, to preserve fish. The market closes at 7:00 p.m. and fish brought there after that hour are simply left to hang in very warm air temperature until the next morning. Fortunately there are remarkably few flies in Tahiti, but nevertheless much of the fish consumed around the island looks far from fresh. It may be because of this general staleness of the raw material that the Tahitians prepare most of their tuna or atule by marinating it in lime juice and salt and then serving it in coconut cream. This is the staple fish dish, but large tuna are sometimes baked in the imu or earth oven.

A good day's catch for a Tahitian tuna boat is said to be 20 to 30 40-pound fish, but from the writer's observations a proportionately larger number of 10- to 20-pound fish would be more usual. The fish are tied by the tails with leaves into bunches of 2 to 8 or 10, depending on the size, hung on a carrying pole, and shoulder-carried about 3 blocks from the quay to the market. At the public market (a concrete-floored, open-sided structure extending clear across one city block) the fish are hung up on iron rails and sold by the fishermen or their womenfolk. No scales are used to weigh the fish. They are sold individually for the most part. Smaller ones are sold by the bunch and the larger tuna are halved or quartered. Prices are arrived at by haggling at each sale, and may vary considerably between the opening and closing of the market. A fair aver-

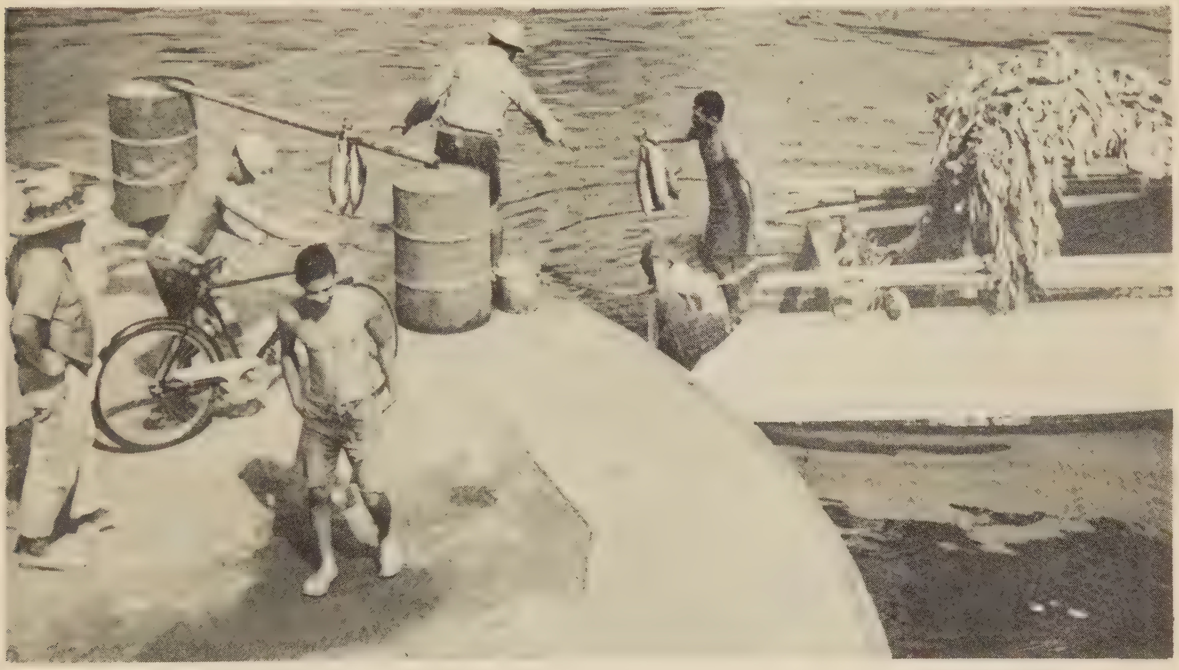

FIG. 3 - TAHITIAN FISHERMEN UNLOADING SMALL YELLOWFIN FROM THEIR BOAT AND HANGING THEM ON A SHOULDER-POLE FOR TRANSPORTATION TO THE MARKET.

age was quoted as 40 to 60 francs (65¢ to $1.00) for a 10-pound tuna. The busiest time at the market is early Sunday morning, when the people who have come into town for Saturday night are purchasing fish and other foodstuffs to take back to the country with them. At such times the market is the scene of extremely spirited activity, and the guards are sometimes hard put to it to maintain order in the surging mob of competing shoppers. Aside from such traffic-directing duties, the chief concern of the market attendants seem to be to see that all fish are hung off the floor on the iron rails provided for that purpose.

A small cannery formerly packed tuna at Papeete, and this was the source of the samples obtained by POFI personnel in the Marquesas. The plant was established in 1939 in connection with a scheme for a pineapple industry, and when this fruit proved to be unsuited to Tahiti's humid climate, the facilities were converted to the processing of yellowfin and skipjack tuna. The pack was put up in tall salmon cans, and most of it was canned in coconut oil, although some imported salad oil was used. The operator used as much hand labor as possible, since labor is fairly cheap in Tahiti, and worked up to a capacity of about 2 tons per day and an output of 2 to 3 thousand cases per year. The average price paid for the fish ran around $80 a ton. No one connected with the enterprise seems to have had any experience in fish packing, and the product, which was not a solid pack, was probably rather crude and variable, but in the years immediately after World War II, when food of any sort was in short supply in Europe, the business prospered. The bulk of the pack was always sent to France. Only a small amount of skipjack in coconut oil was sold in French Oceania.

With the return of normal market conditions in France, this unorthdox product became less saleable, and the cannery finally ceased operations in 1947. The machinery has been dismantled and stored, and has been up for sale for several years. The former operator ascribes the failure of the enterprise to the irregular and unpredictable supply of fish, the reluctance of jobbers to handle such a small number of cases, and the effects of unsettled world conditions and transportation difficulties on his supply of imported materials, chiefly tin plate.

The story of tuna canning in Tahiti is in part merely a repetition of the same sad tale which has been heard from other Pacific islands where the development of a tuna industry has been tried--"no bait." Without the use of live bait, not enough fish could be taken out of the surface schools to keep the cannery supplied, and the local fishermen lacked the knowledge and probably the capital to try long-lining. Vessels from Hawaii with experienced live-bait fishermen prospected in Tahitian waters, but were unable to find any adequate source of bait. Whether or not a tuna-canning industry can be supported by long-line fishing in the central Pacific is a question which must wait until someone makes the attempt, but the Tahitian experience seems to indicate that fishing the surface schools by the Polynesian method, without the advantage which live-bait confers, will not give enough return per unit of effort to produce a surplus of fish for canning.

On the other hand, the existing tuna fishery at Tahiti is evidence of the fact that an adequate supply of fresh tuna for an island population's needs can be obtained in the ancient Polynesian way even in the absence of a live-bait supply. Islands where the supply of protein food is inadequate, where there are suitable stocks of tunas in nearby waters, and where the natives are willing to exert themselves to catch tuna and to eat them once they are caught, would appear to be promising locales for the introduction (or reintroduction) of this method of fishing.

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SPECIAL SECTION

How the Menhaden Industry Can Profit From Biological Research

By Lionel A. Walford
Chief, Branch of Fishery Biology
United States Fish and Wildlife Service

IN ALL the sciences, the research that has proved in the long run to be most profitable started out with no promise of benefit—financial or otherwise. Research conducted merely for the love of exploring the unknown and adding to human knowledge—that is the kind that has led to the greatest advances of human material welfare. I believe the menhaden industry people, too, would profit most from research begun in that spirit—of learning more about the animal which furnishes their living. Even so, any fishery scientist would begin with the problem of fluctuations and their causes, which also happens to be one of greatest economic interest.

We recognize, as a matter of course, that conditions on land change constantly. We see it happen before our eyes. We read about it in records that go as far back as history goes—records of droughts and floods, famines and gluts, plagues of diseases and of pests, and so forth. There is even more dramatic evidence in the rocks where we find the remains of animals and plants that once flourished in enormous abundance and now no longer live anywhere.

It is very easy for us to notice brief abnormalities in the environmental conditions that affect our lives, like a cold winter, a late spring, a flood, an epidemic, a plague of locusts. But the slow trends that involve minute changes in average conditions from one year to another or even from one decade to another, escape our notice until they have been in progress for a long time. This is even more true of the sea than of the land, for we cannot perceive the changes that occur there, and there are not nearly so many means of keeping a record of them. Think of weather alone. Every community keeps account of its temperature and rainfall; every newspaper publishes the information daily, with the Weather Bureau's prediction of what conditions will prevail the next day; so that if anyone wanted to study records of weather on land to see how they are related to fluctuating crops, it would be easy enough to do so. When it comes to the ocean there are very few places anywhere in the world where people systematically observe and record the acquatic climate. By systematically, I mean day after day, year in and year out, from sea surface to bottom. This kind of thing requires special equipment, including research ships, and especially educated scientists, and boundless patience over the long periods of time when the records seem to be not leading to anything of practical intrest.

And yet, eventually they do prove to be of the greatest practical interest to fishermen, for the most baffling mystery to puzzle anyone who has anything to do with fish or fishing is the fact of fluctuation. Fish move all the time, sometimes simply grazing about in the ocean meadows, like cattle, sometimes following rapid, purposeful migrations to spawning or feeding grounds; but the courses of their movements are no more fixed than are the shifting courses of the ocean currents through which they move. Thus their accessibility to fishermen fluctuates. A species of fish might come in close to shore seasonally in dense masses as regularly as clockwork, then all at once fail to appear one year. They might still be in the ocean all right, but be just beyond reach of the fisherman's usual beat. That happens more often with surface-swimming fishes like menhaden, pilchards, herring and mackerel, than with bottom-living fishes like cod and flounder. Not only does their accessibility fluctuate, however; their actual abundance fluctuates too, depending on the size of individual year broods, which may vary, from the smallest to the largest, by a ratio of as high as one to fifty. A single year brood is sometimes large enough to sustain a fishery through several years, and an intensive fishery may depend wholly on the frequent enough occurrences of such a brood. Thus the decline of the Pacific pilchard fishery is in large part attributable to the occurrence of a long series of years when only poor year broods appeared within the range of the fishery.

A consequence of all this is that stocks of fishes vary in size from one year to another. Thus a tremendously large year brood appearing in the fishery for the first time can overwhelm the catch with small fish; but in succeeding years as they grow larger, the size composition of the catch increases accordingly.

The environments of sea fishes are exceedingly complex. The principal characteristics of the water—temperature and content of nutrient salts—vary seasonally, and from year to year in response to changes in meterological conditions. These changes control the abundance of the myriads of small creatures—plant and animal—on which the smaller fishes depend. These, in turn, feed the larger fishes of prey. So a change in any part of this web of life can profoundly affect all the other parts of it. The quantity of plankton varies; so

Menhaden

does its quality. Thus the microscopic plants which animals of the plankton eat, and which are important in the diet of menhaden too, can be predominantly carbohydrate, protein or fat, depending on the prevailing conditions. This should be of great interest to menhaden processors because it has much to do with the oil content of their fish.

How can biological research be of practical use if it is concerned with things that we can do nothing about, like climate, weather, ocean currents, and the fertilization of the water by transport of nutrient salts from the depths to the surface? I think in this way: By intensively studying these various elements of the ocean environment, we will eventually come to understand how they act on fishes to affect their abundance and movements. That understanding would make it possible to predict abundance, and to know just where to look for fish when they make one of their episodic disappearances. And that, everyone concerned agrees, would be very useful knowledge indeed.

Because menhaden are affected in some degree by each of the animals and the plants that share their environment, biologists would have to take them all into account in their research. There is another animal, however, which affects the menhaden very much more than all the others, which the biological researchers would also have to take into account, and that animal is man, whose numbers and activities fluctuate too. Man may be subject to cycles in abundance, but we have no way of knowning about that; because records are not good enough, recorded history is too short, and man has the unique ability to modify his own environments and destiny. However, in doing that he also modifies the environments and destinies of the other creatures of the earth, sometimes with full knowledge of what he is doing, but usually not.

That fact is more important to the menhaden industry than to most other marine fisheries, because unlike most other sea fishes, the menhaden depends on an environment which man can and does affect.

So far as we know now, menhaden spawn very close to shore, and in estuaries and bays. The eggs soon hatch and the larvae transform into active swimming little fish which work their way far up into the intricate system of backwaters, sloughs, and marshes that borders the whole Atlantic Coast. These rich inland waterways, nourished by the minerals which the rivers carry down from the land, are the nursery grounds of young menhaden. Whatever events may determine whether a menhaden brood will yield a bumper crop or a failure, those events must happen in the marsh area; for it is there that the young fish live during their most critical months of life.

Thus anything man does to the marsh—and he works on it all the time—must, in the long run, influence the abundance of menhaden. Pollution, diking, draining, reclaiming, improvement for navigation purposes—each of these processes must have its effect. Sometimes the effect may be beneficial, but no one can know without first learning to understand the relation between the elements of the marsh environment and the fish. Any changes in the abundance of menhaden brought on by changes in the marsh would be so slow as to be barely perceptible. It is for that reason that a program of menhaden research should be centered on the marsh area to accumulate the records that in time would yield the key to understanding and predicting the short-term fluctuations as well as the long cycles, and to detecting the dangerous trends brought on by man's civilizing activities.

"How Can the Menhaden Industry Benefit by Research," by Dr. L. A. Walford, was a speech given at the annual meeting of The Virginia Fishermen's Association, Reedville, April 28, 1953.

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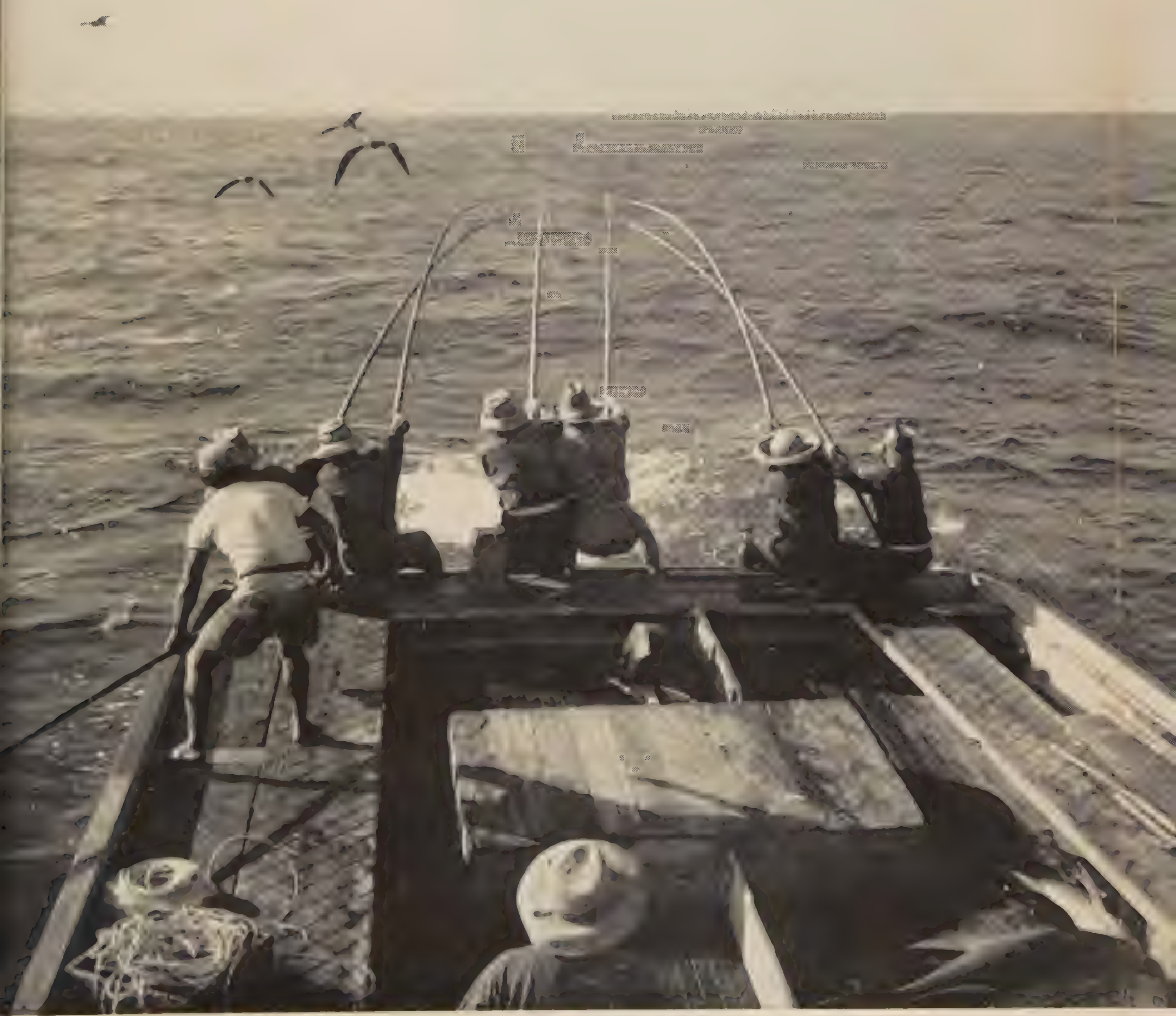
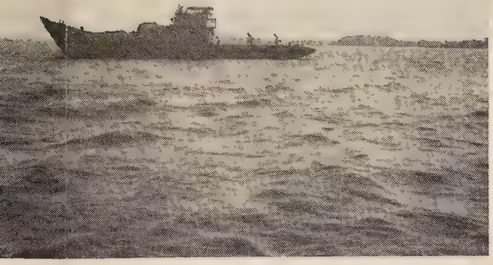
Sampan from Hawaii

Makes Visit to

LINE ISLANDS



Hooking and landing a "6-pole" yellowfin on "The Tradewind"
Fanning Island, February 1953



The sampan, Tradewind, at anchor in the lagoon, Palmyra Island, January 1953.

Sampan from Hawaii Makes Visit to LINE ISLANDS

By
HEENY S. H. YUEN
JOSEPH E. KING
Fishery Research Biologists
Pacific Oceanic Fishery Investigations
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Honolulu, T. H.

TUNA fishing on a commercial basis was conducted in the area of the Line Islands during January and February, 1953, by the *Tradewind*, an 80-ft. sampan typical of Hawaii's pole-and-line tuna fleet. This vessel, owned by the Tradewind Fishing Company of Kauai, was captained on the expedition by Mr. Junji Higaki and manned by a crew of eight.

The Line Islands lie about 1,000 miles south of the Hawaiian Islands and are beyond the present range of Hawaii's fishing vessels (see accompanying chart). The trip of the *Tradewind* was the first attempt of a Hawaii-based sampan to live-bait fish for tuna in the area. The *Oregon*[1], operated by the Pacific Exploration Company, prospected for tunas in the Line Islands in February 1948. Some bait fish, consisting of mullet and goatfish, were obtained from the island lagoons; several schools of skipjack and a few schools of yellowfin were worked but with little success. The *Calistar*[2], a West Coast tuna clipper, visited the Line Islands on an exploratory fishing cruise in February 1949. With bait brought with them from the West Coast, they managed to catch about 50 tons of yellowfin at Fanning Island and 15 tons of yellowfin at Palmyra Island.

The Pacific Oceanic Fishery Investigations of the Fish and Wildlife Service, with headquarters in Honolulu, has carried on experimental fishing in the Line Islands employing live-bait, longline, trolling and purse-seine. The results of these studies indicated that the waters in the vicinity of the Line Islands were relatively high in tuna abundance and could possibly support a small-scale fishery.

Since this organization was interested in observing the success of a commercial venture in the area the research vessel *Hugh M. Smith* was assigned to transport fuel and ice for the sampan and to freeze her catch of fish. During three weeks that the sampan fished, the *Smith* carried out a hydrographic and longline fishing survey around the islands.

The *Tradewind* began fishing at Palmyra Island (January 12 to 24), then shifted to Christmas Island (January 26 to February 3), and ended up at Fanning Island (February 4 to 7). The locations of fishing areas are shown on the accompanying chart. Palmyra is the northernmost of the Line Islands (except for the barely emergent Kingman Reef) and the nearest to Honolulu. During 12 days spent there the *Tradewind* managed to obtain about 1,000 lbs. of live-bait, and caught about seven tons of yellowfin tuna.

Numerous schools of yellowfin and one mixed school of yellowfin and skipjack were seen within 15 miles of the island. The chief factor limiting the tuna catch was the scarcity of bait. Mullet of two species, three to 10 inches long, were the only bait fishes available in the accessible areas of the lagoon and outer beach and the supply of these soon ran out. One day was spent investigating the possibilities at Kingman Reef, but tuna was sparse and sharks were numerous enough to constitute a dangerous nuisance.

In hopes of finding a better supply of bait the *Tradewind* then proceeded to Christmas Island. Numerous skipjack schools were present close-in to the island, but no yellowfin schools were sighted. Initial baiting attempts yielded primarily goatfish eight to 20 inches in length, which were too large to work the skipjack schools.

The crew then turned to reef fishing and in four days caught about 2 ton of "papio" (one of the jacks, or pompano-like fishes), a highly prized fish in the Honolulu markets. A later attempt to catch bait yielded about 300 lbs. of mullet, but as there were apparently no yellowfin in the area the vessel ran back to Fanning Island.

During the stay at Fanning a fair amount of bait (about 850 lbs. of mullet and small milkfish) was obtained from the lagoon, resulting in the capture of about 6½ tons of yellowfin from along the west side of the island. The tuna schools were small and few in number, however, and the sharks, which are very abundant in these waters, tended to discourage the tuna from approaching closely to the stern of the boat.

An accounting of the time from departure from Honolulu on January 8 to return on February 12, shows that 13 days were spent in running, seven days baiting, eight days tuna fishing, four days market fishing, two days transferring fish, fuel, and supplies between the *Tradewind* and the *Smith*, and on two days the vessel was weather-bound.

The total catch was approximately 13½ tons of yellowfin and about 2 tons of "papio." Most of the yellowfin schools were mixed as to size of fish with individuals ranging from five to 190 pounds, but the average for the trip was about 15 pounds.

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[1] Smith, O. R., and M. B. Schaefer. Fishery exploration in the western Pacific (January to June, 1948, by vessels of the Pacific Exploration Company). U. S. Fish and Wildlife Service Commercial Fisheries Review, Vol. 11, No. 3, p. 1-18, 1949.

[2] Anonymous. **Calistar** finds tuna in mid-ocean, but fish are wild and bait scarce. Pacific Fisherman, Vol. 47, No. 6, p. 47, 49. 1949.

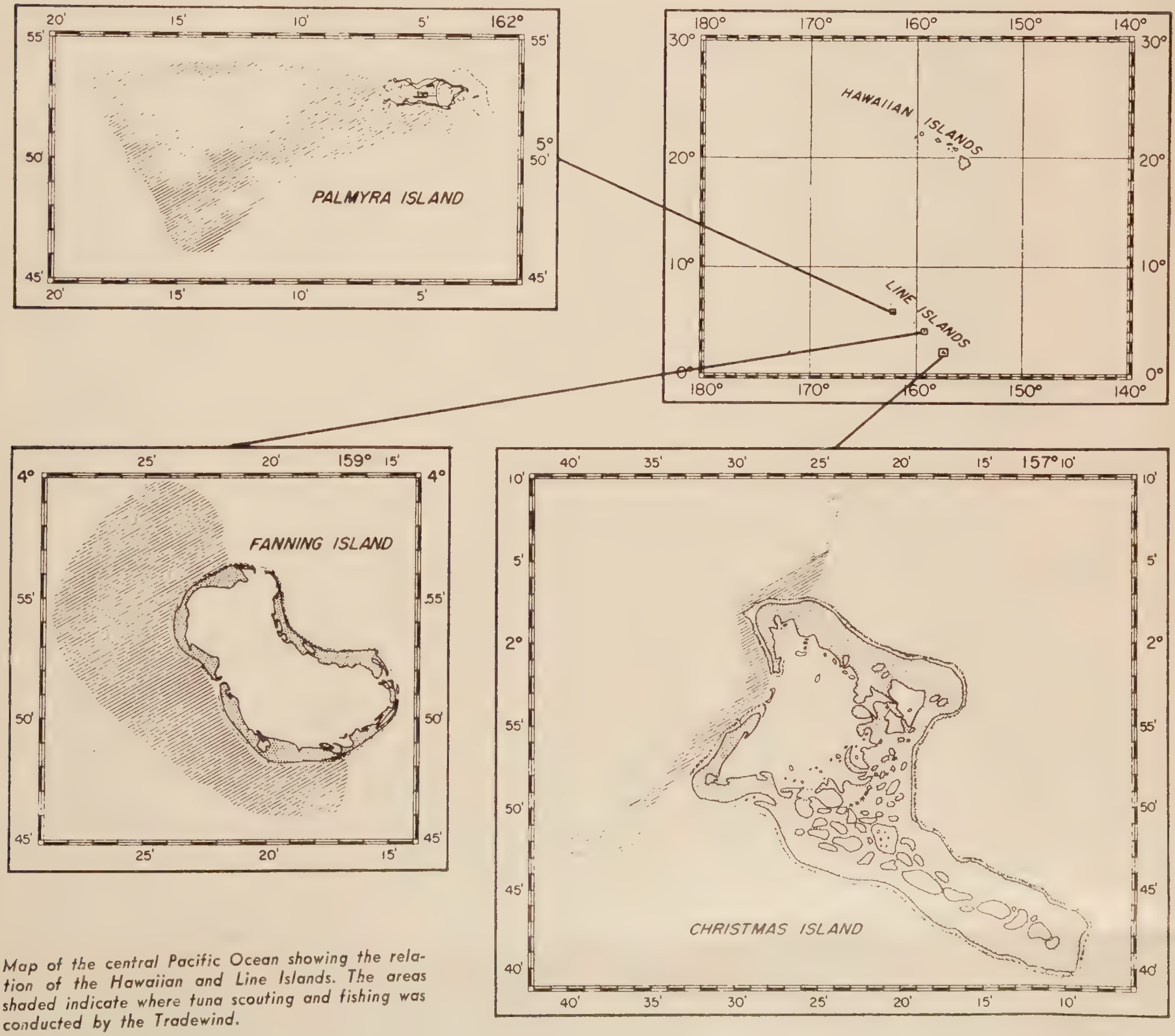
The weather encountered during the cruise varied from unfavorable conditions of rain, poor visibility, and rough seas experienced at Palmyra and Christmas Islands during the early part of the cruise, to excellent weather and calm to moderate seas during the stay at Fanning Island and on the run home.

The Line Islands are of sufficient size to provide lees where vessels can obtain shelter if necessary. All the islands have fair anchorages, but Palmyra is the only island of the group with a navigable channel (depth about 5 fathoms) into the lagoon and dock facilities for fishing vessels. Fresh water and, usually, fuel can be obtained here.

Palmyra Island and Kingman Reef

(Continued on next page)

Live-bait fishing for 10 to 20 pound yellowfin tuna with 1- and 2-pole rigs; Fanning Island, February 1953.


PALMYRA ISLAND
20'
15'
10'
5'
162°
55'
50'
45'
5°
HAWAIIAN ISLANDS
LINE ISLANDS
180°
170°
160°
150°
140°
30°
20°
10°
0°
FANNING ISLAND
25'
20'
159°
15'
4°
55'
50'
45'
CHRISTMAS ISLAND
40'
35'
30'
25'
20'
15'
157°
10'
10'
5'
2°
55'
50'
45'
40'

Map of the central Pacific Ocean showing the relation of the Hawaiian and Line Islands. The areas shaded indicate where tuna scouting and fishing was conducted by the Tradewind.

The Tradewind crew making a haul for bait along outer beach; Palmyra Island, January 1953.

Sampan Visits Line Islands

(Continued from preceding page)

are U. S. possessions, Fanning and Washington Islands are British owned, and both countries claim Christmas Island. Therefore a fishing vessel wishing to work throughout the area can expect to encounter difficulties in securing baiting and fishing rights in certain of the islands. Another complicating detail is the fact that fish caught within the recognized boundaries of the British-owned islands must be declared as foreign cargo upon entering any U. S. port.

This cruise of the *Tradewind* and previous surveys of the Fish and Wildlife Service demonstrate that considerable numbers of tuna are present both at the surface and in the subsurface waters of the Line Islands group during the winter months, the off-season in the Hawaiian skipjack fishery.

If the 13½ tons of tuna caught by the *Tradewind* is compared to the 1½ tons which a boat would normally catch in a month in Hawaii from December through March (based on records of the Territory of Hawaii for the past five winters, it would seem to be quite beneficial to the Hawaiian tuna industry to have at least part of its fleet operating in the Line Islands area during this period.

Before this can be done, however, there are several problems to consider. The average sampan has a capacity of only 15 tons, no mechanical refrigeration facilities, an insufficient range for such a long trip, and no qualified navigator.

One possible solution to these problems would be to have several boats fishing together accompanied by a tender. The scarcity of bait poses another problem. A promising bait substitute which the University of Hawaii is attempting to develop under the auspices of the Fish and Wildlife Service may eventually remedy this situation.

Thus it appears that the present barriers to the exploitation of tuna in the Line Islands may possibly be hurdled to permit profitable winter trips for a limited number of Hawaii-based vessels.

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